



HUGHES STX CORPORATION

December 19, 1996

NASA Headquarters
 Acquisition Division
 Code HWC
 Washington, DC 20545-0001

INTERIM

TN-92-CR

OCIT

004 866

Attention: Julie Speers
 Contract Specialist

Subject: Annual Technical Presentation

Reference: Contract No. NAS5-31755 (3067)

In Reply Refer To: 96-LEW-0622

Dear Ms. Speers:

Enclosed please find the latest technical presentations for HSTX Contract No. NAS5-31755. These presentations have been distributed as instructed by the referenced contract Article F.4. Should additional information be required, please contact the undersigned at (301) 794-5167.

Sincerely,

Hughes STX Corporation

Lori E. Weber
 Lori E. Weber
 Manager, Contract & Pricing

cc: NASA Headquarters
 New Technology Representative
 Code CU
 Washington, DC 20545
 Attn: New Technology Representative (1 Copy)

NASA Center for Aerospace Information (CASI)
 800 Elkridge Landing Road
 Code CU
 Linthicum Heights, MD 21090-2934
 Attn: Accessioning Department (Reproducible +2 Copies)



HUGHES STX CORPORATION

NASA Headquarters
Code YSM
Washington, DC 20546
Attn: J. Kaye, NASA Technical Representative (1 Copy)

Solar Spectral Irradiance Variations

Observed by NOAA-11 SBUV/2 During 1989-1994

Matthew T. DeLand, Richard P. Cebula

*Hughes STX Corporation
Greenbelt, MD*

Ernest Hilsenrath

*NASA Goddard Space Flight Center
Greenbelt, MD*

presented at the 1996 Fall American Geophysical Union Meeting, San Francisco, CA

19 December 1996

supported by NASA Grant NASW-4864

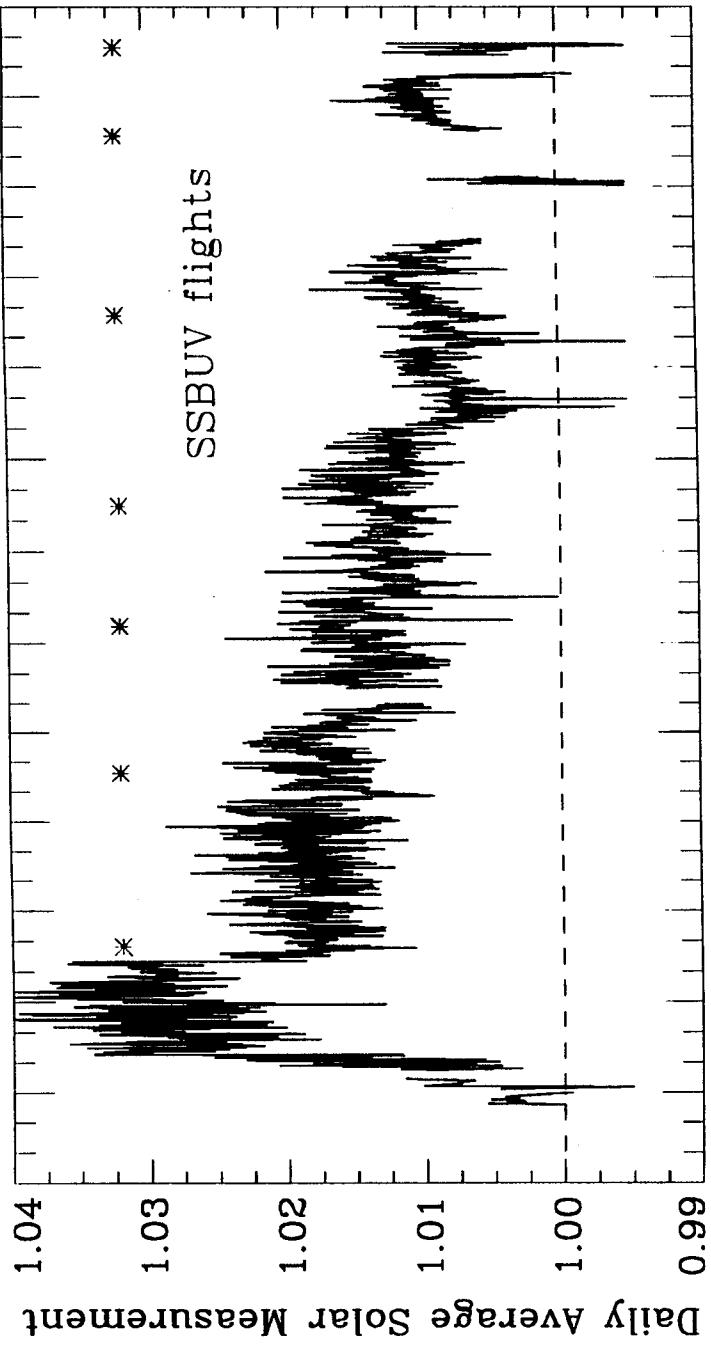
The NOAA-11 SBUV/2 instrument made daily measurements of the solar UV irradiance between 160 and 405 nm at 1.1 nm resolution from December 1988 to October 1994, covering the maximum and declining phase of solar cycle 22. Instrument sensitivity drift was significant, ranging from approximately 30% near 200 nm to roughly 4% near 400 nm. These changes are 3-4 times larger than the predicted solar irradiance variations in the middle UV and near UV over a solar cycle. The SBUV/2 data have been reprocessed using a long-term characterization determined from both internal and external sources. An onboard calibration system was used to monitor long-term diffuser reflectivity changes, and comparisons with coincident flights of the SSBUV experiment were used to remove additional NOAA-11 instrument sensitivity drift.

We present NOAA-11 solar UV irradiance observations during 1988-1994 for spectral regions which drive atmospheric photochemistry. The NOAA-11 results indicate a decrease of approximately 5-7% at 205 nm from the maximum of solar Cycle 22 in 1989-1991 through the end of the NOAA-11 record in October 1994, well into the declining phase of Cycle 22. The NOAA-11 irradiance data indicate an upper limit of roughly 1.5% on long-term solar change between 290-310 nm during this period, consistent with predictions from proxy indexes and scaling functions. We will also compare the NOAA-11 observations to the daily spectral irradiances from the UARS SUSIM V16 and UARS SOLSTICE V8 data sets, both of which cover the period September 1991 - October 1994.

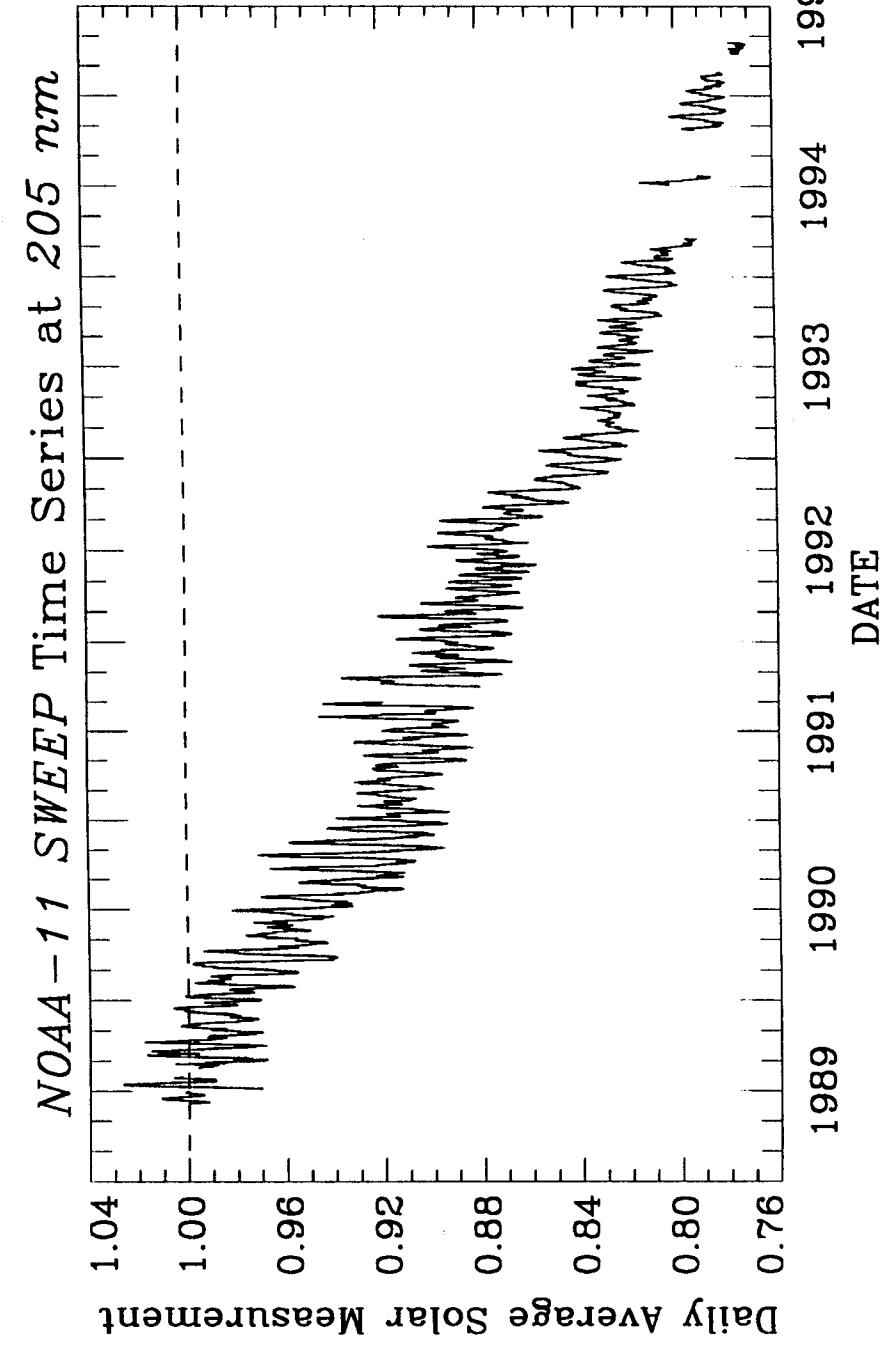
- ▶ SBUV/2 onboard calibration system monitors diffuser reflectivity **only**. Long-term diffuser degradation has been removed from time series.
- ▶ Remaining instrument response changes are ~2% near 400 nm, 20% at 200 nm.
- ▶ Short-term solar variations visible at 205 nm, but long-term change cannot be evaluated.
- ▶ 7 SSBUV flights available for coincidences during 1989-1994.

NOAA-11 *UNCORRECTED* Data

NOAA - 11 SWEEP Time Series at 391 nm

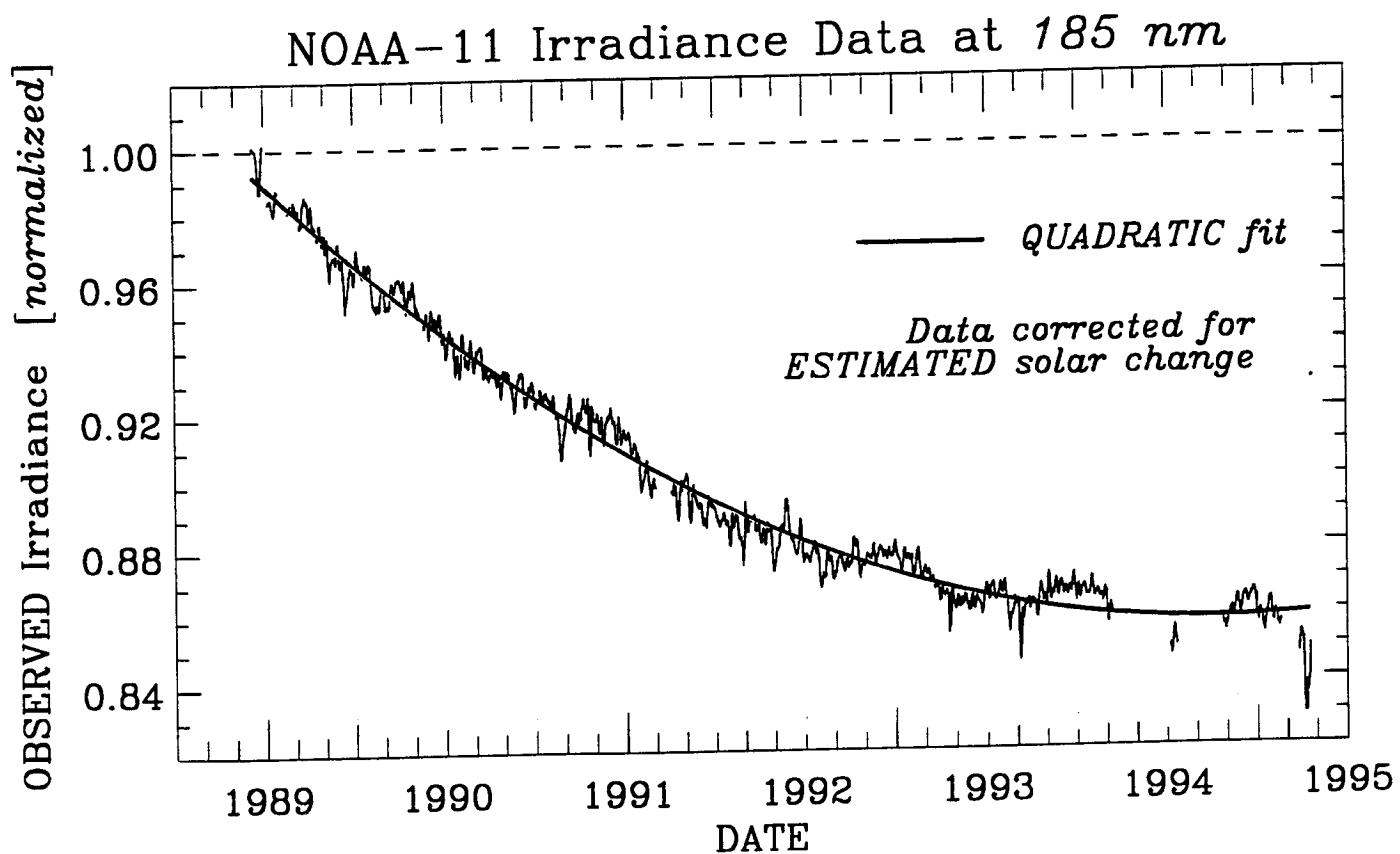
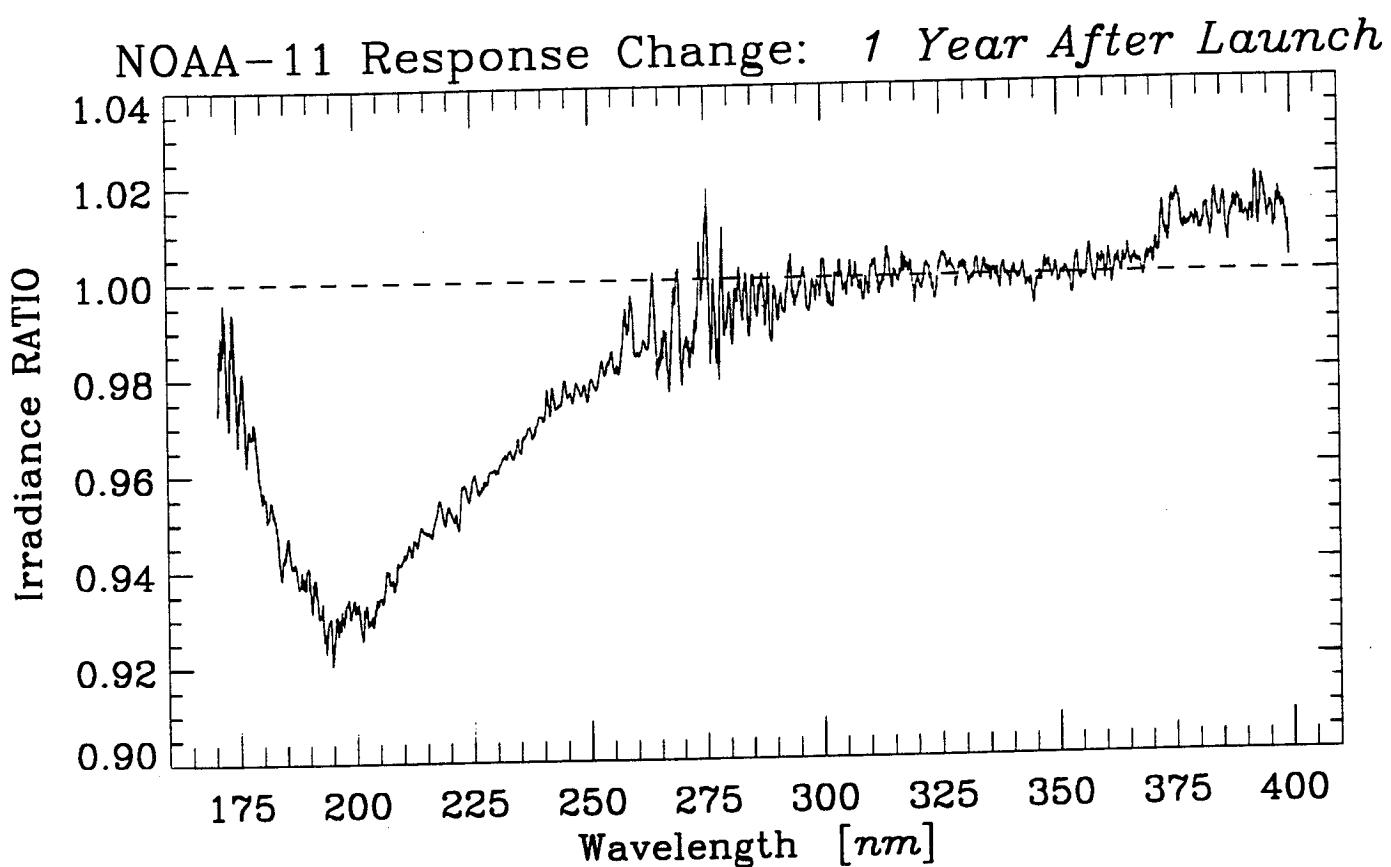


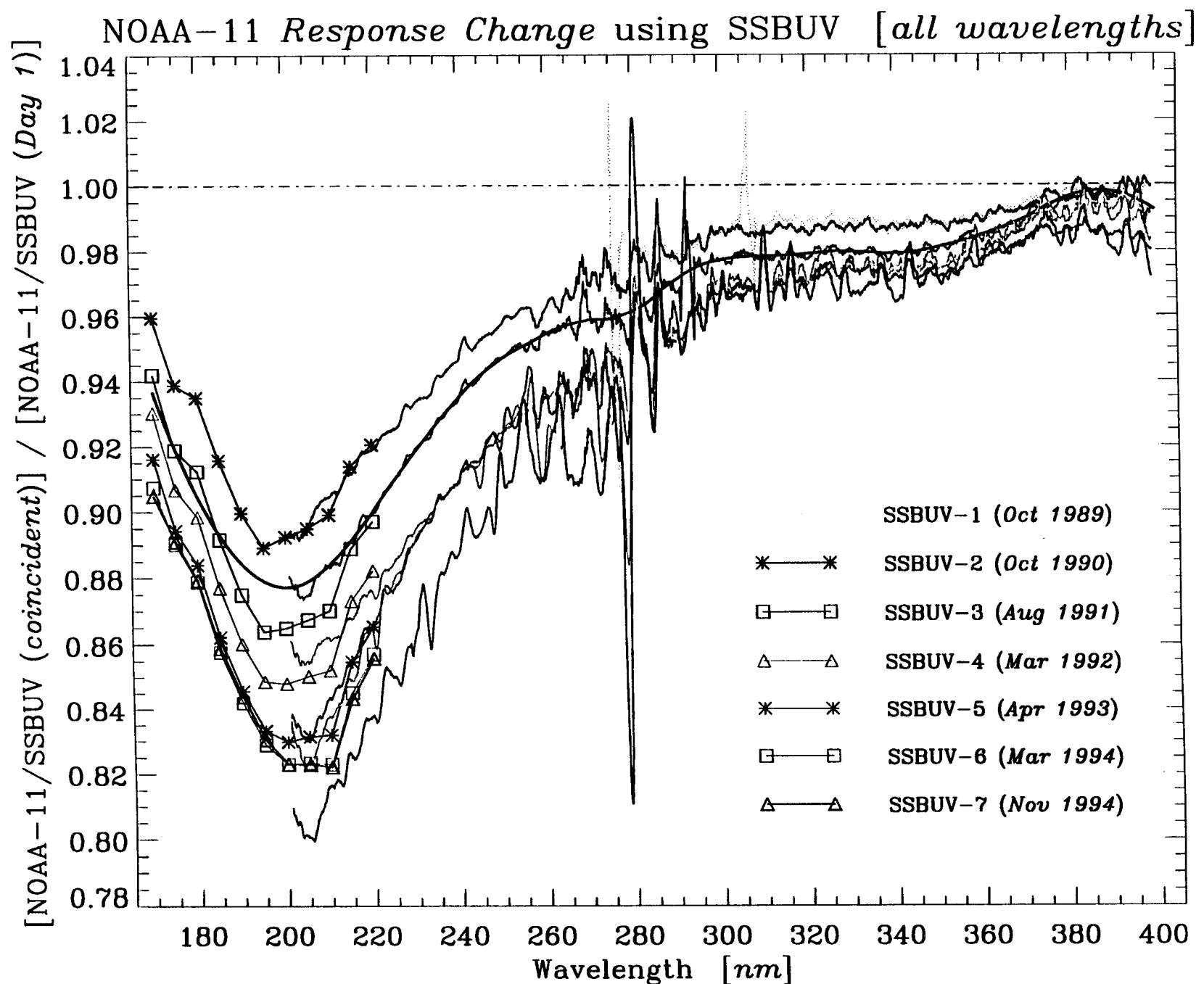
NOAA - 11 SWEEP Time Series at 205 nm



- ▶ SSBUV absolute irradiances in good agreement with other instruments ($\pm 2\%$ vs. UARS, ATLAS means).
- ▶ SSBUV long-term calibration for 200-400 nm wavelength region repeatable to approximately 1.0-2.4%.
- ▶ NOAA-11 "Day 1" irradiance agrees with SSBUV reference spectrum to approximately $\pm 5\%$, with some spectral bias.

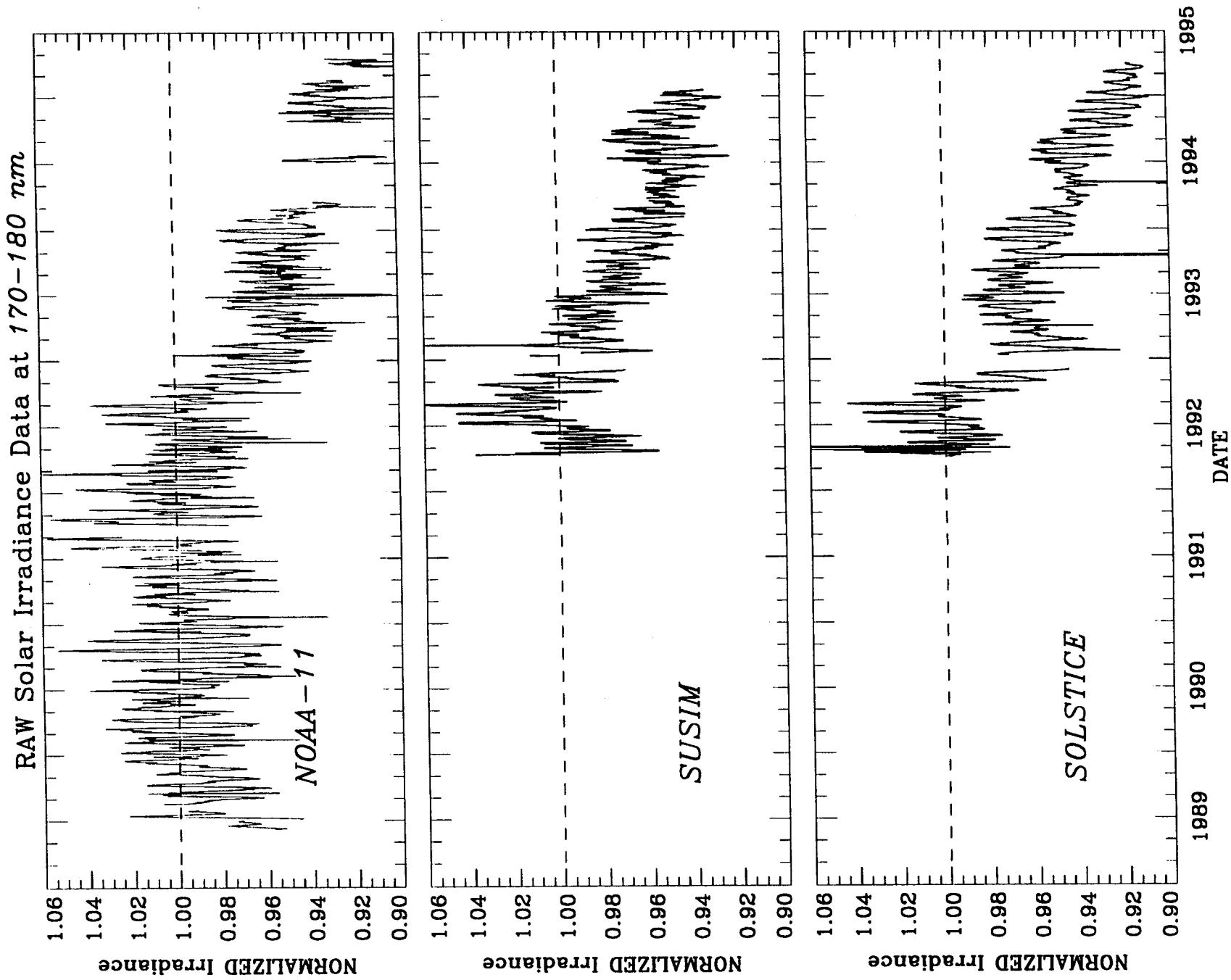
SSBUV Absolute Irradiance Comparison



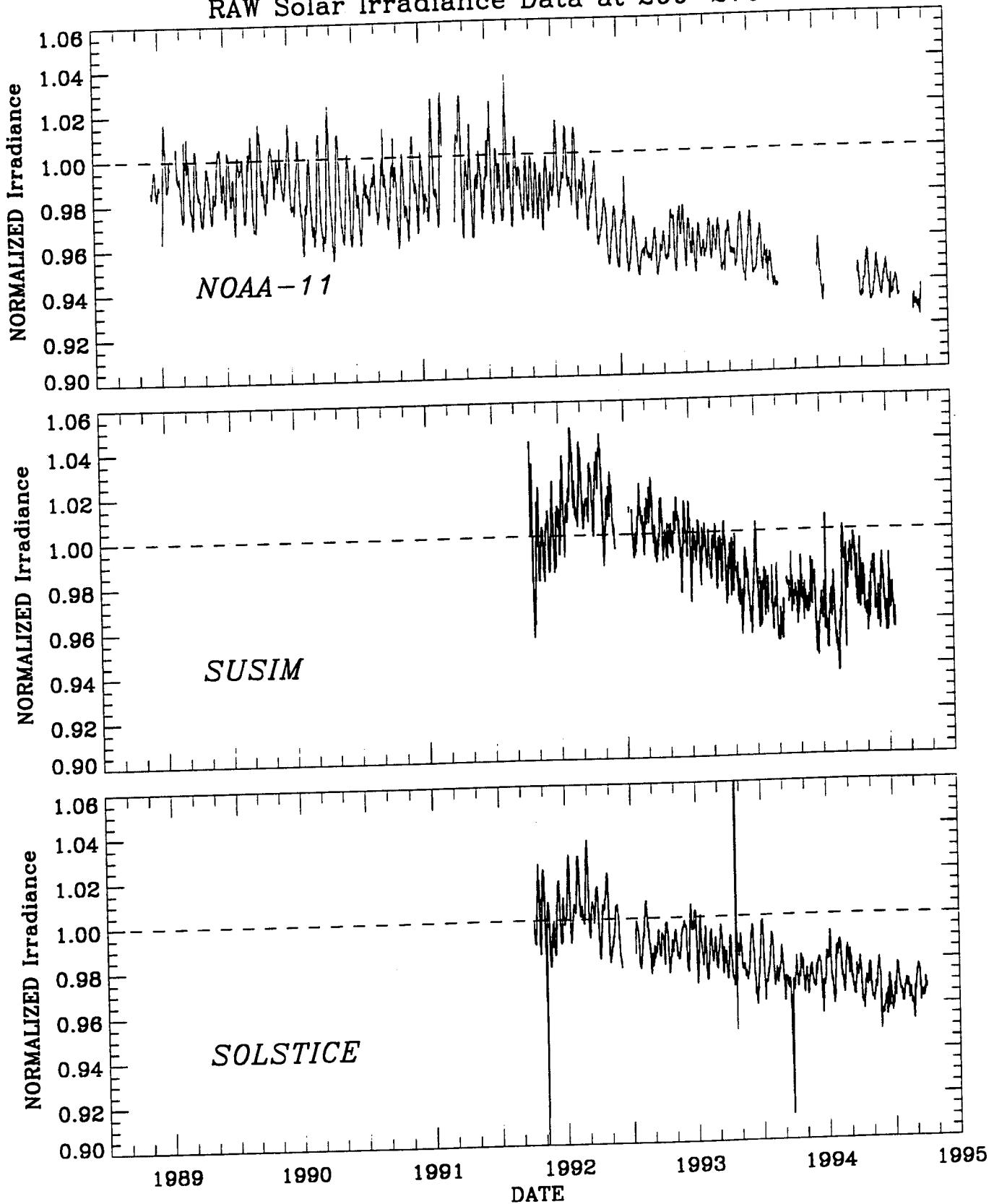


- ▶ Reprocess all NOAA-11 data with corrections for instrument degradation (*derived here*), wavelength scale drift, orbit drift (*goniometry*).
- ▶ NOAA-11 results shown are 1 nm averaged spectra on 0.5 nm centers, for best comparison with UARS SUSIM [*V16*], UARS SOLSTICE [*V08*].
- ▶ Daily noise for 10 nm band averages approximately $\pm 0.5\%$ at short wavelengths, $\pm 0.2\%$ at long wavelengths ($\lambda > 300$ nm).
- ▶ Current NOAA-11 sensitivity change correction leaves long-term residuals of $\sim 1\text{-}2\%$ at long wavelengths. This accuracy is comparable to SUSIM, SOLSTICE.

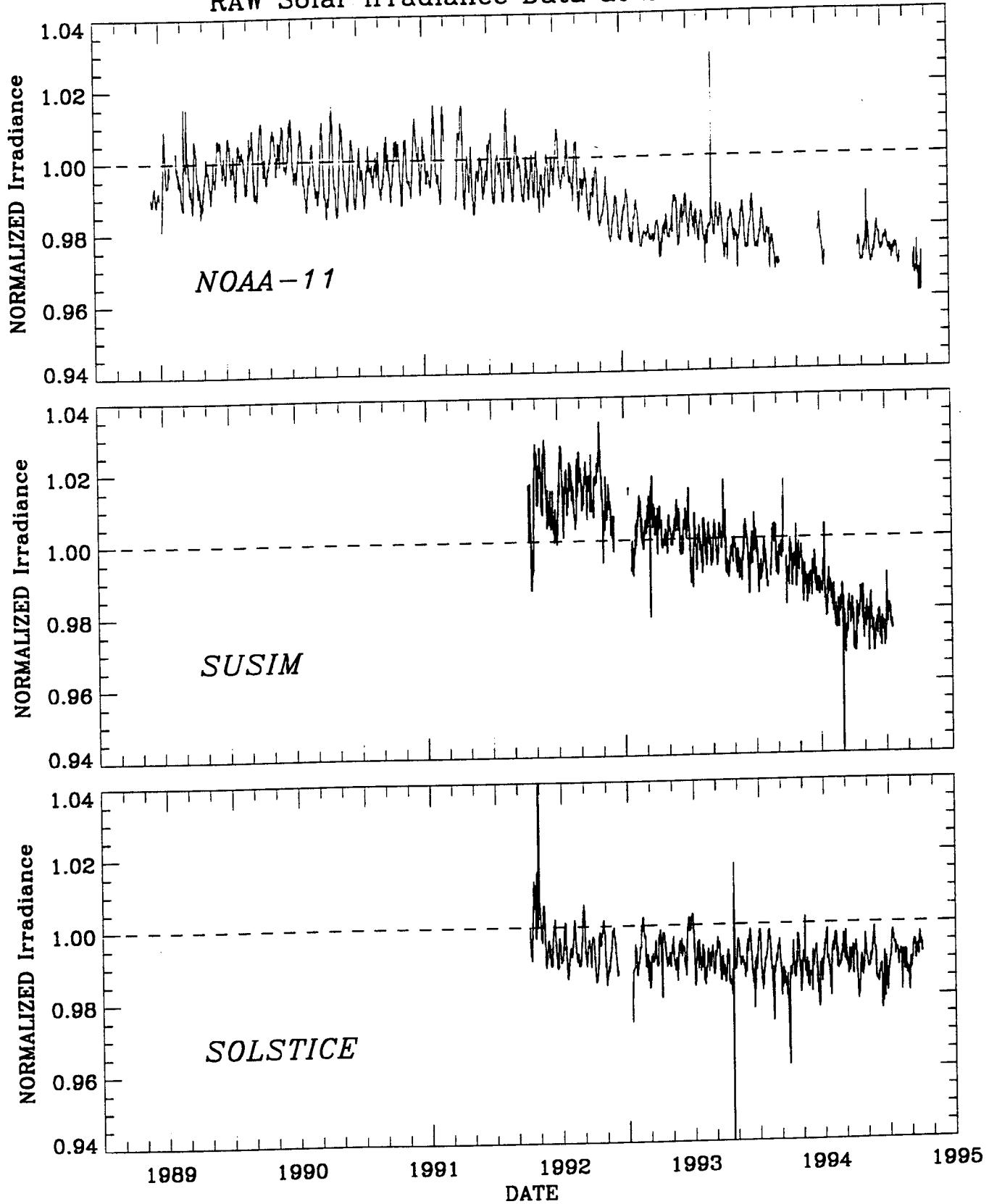
NOAA-11 Corrected Data VS. UARS Instruments



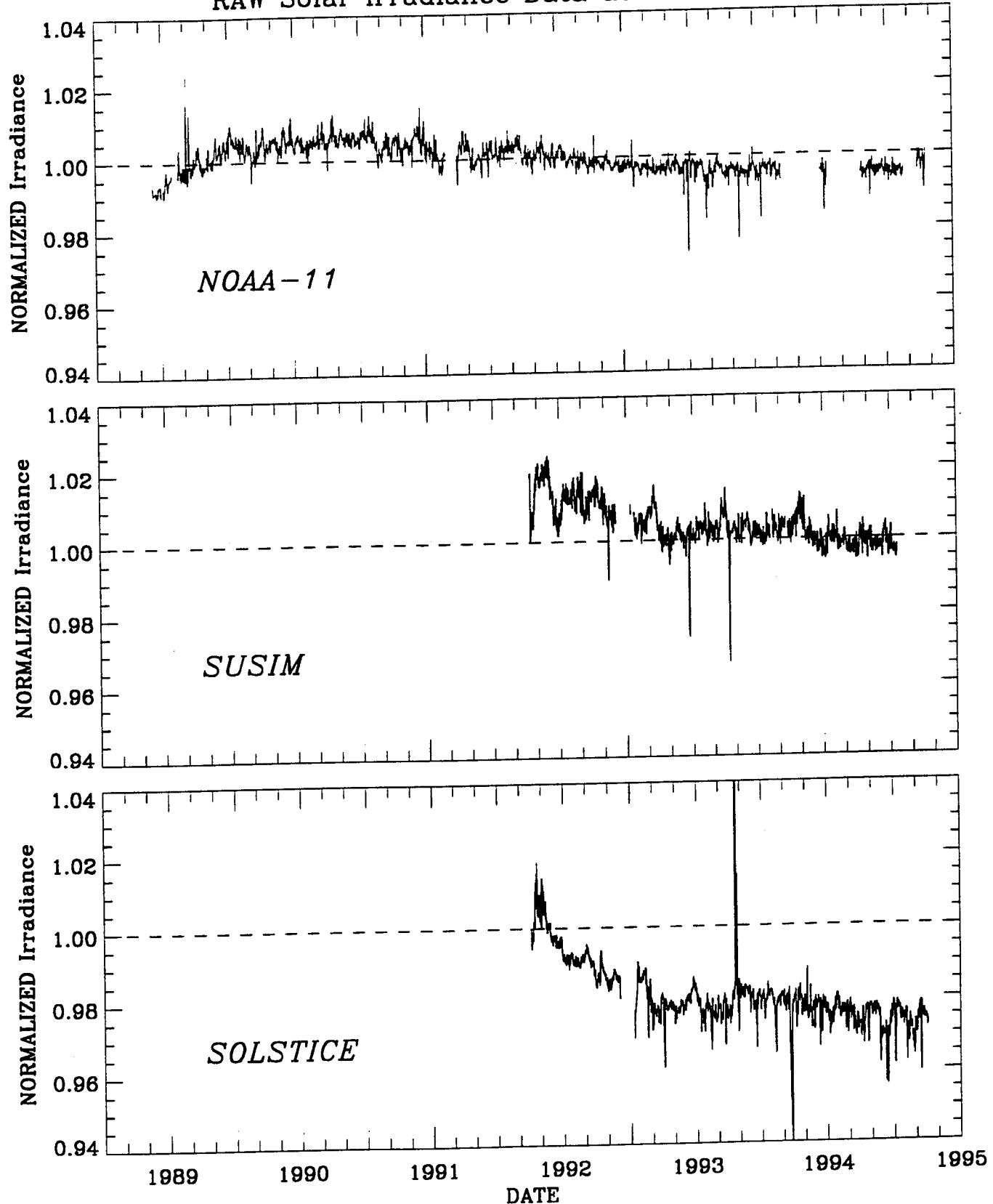
RAW Solar Irradiance Data at 200–210 nm



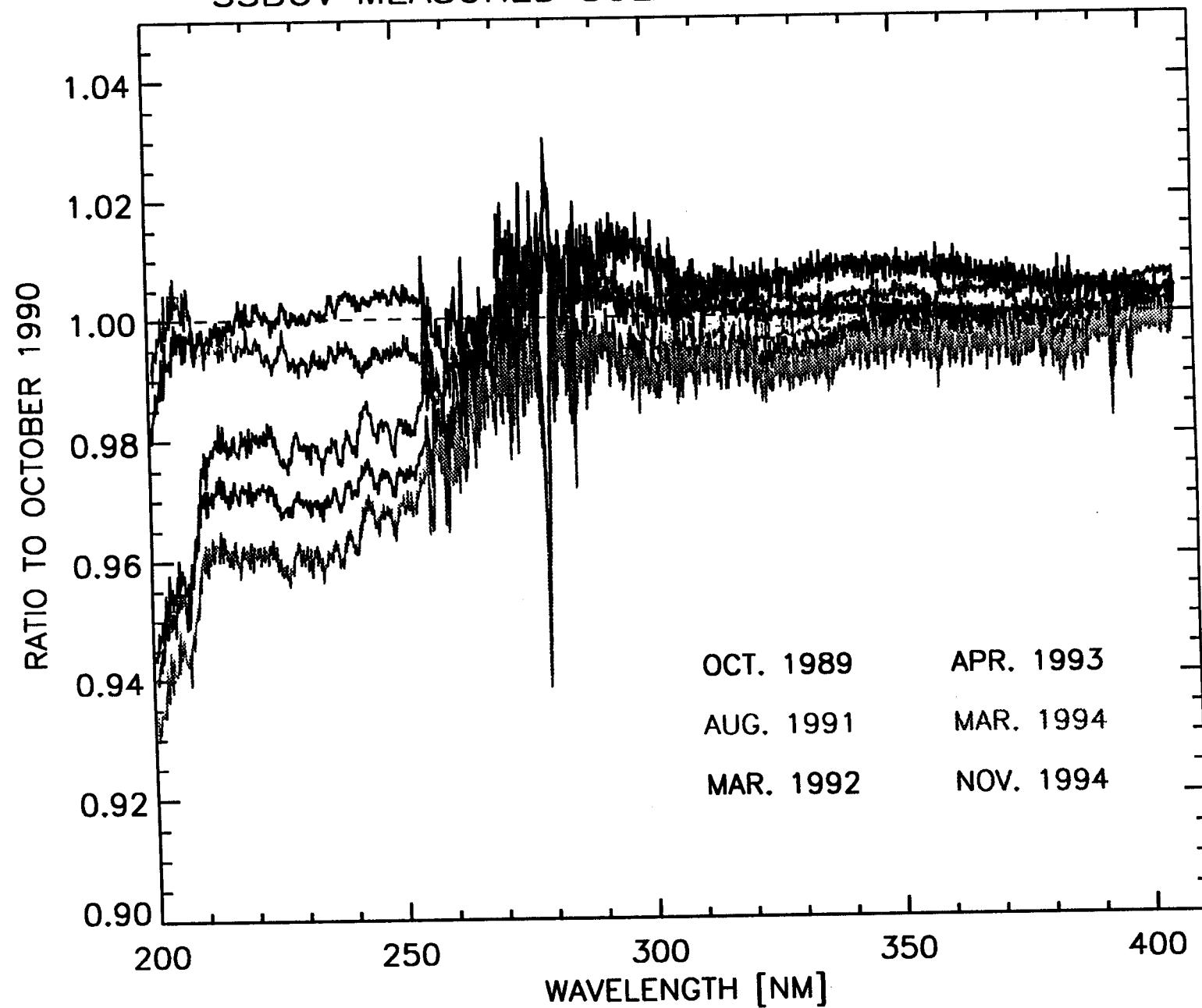
RAW Solar Irradiance Data at 240-250 nm

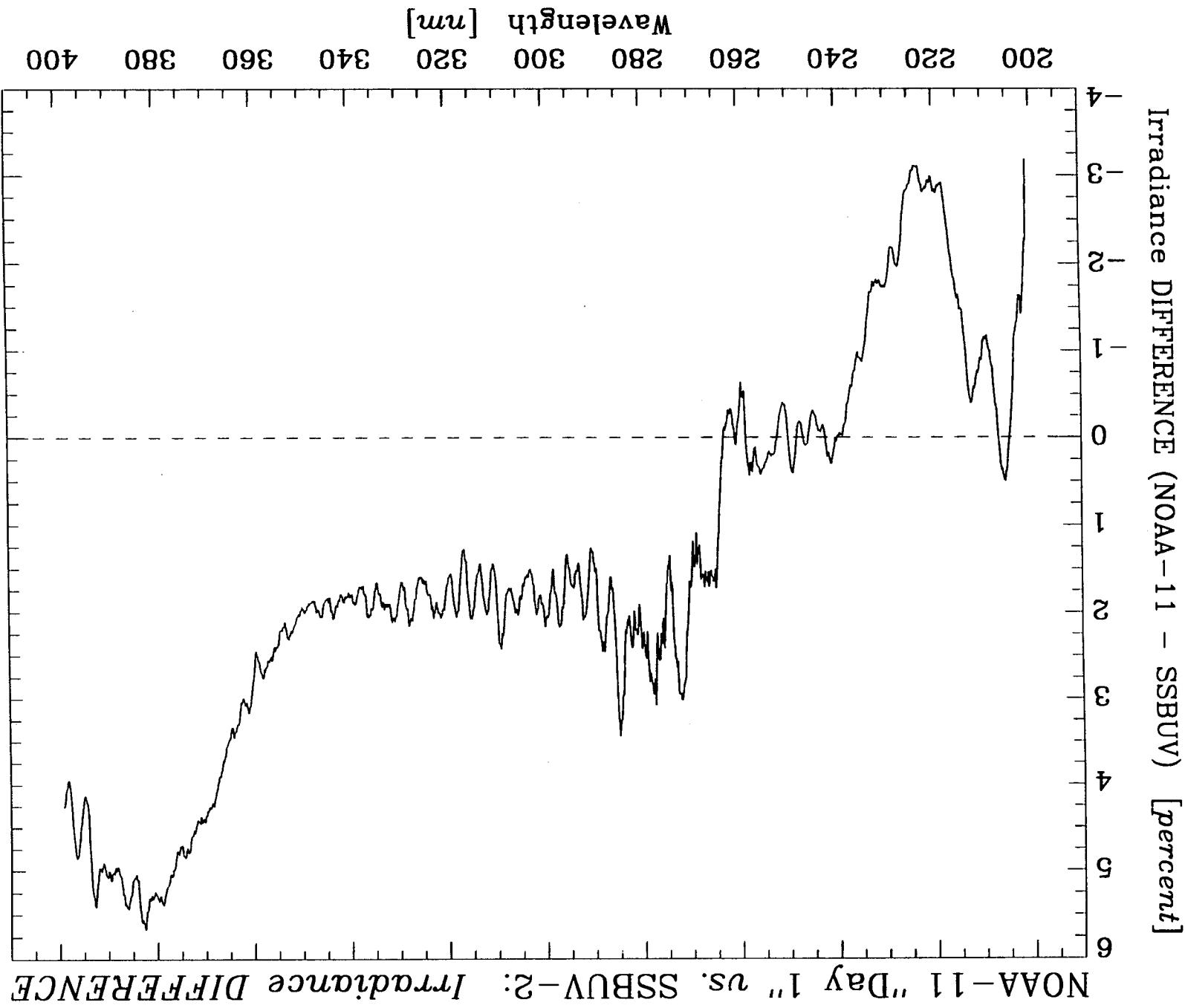


RAW Solar Irradiance Data at 290–300 nm



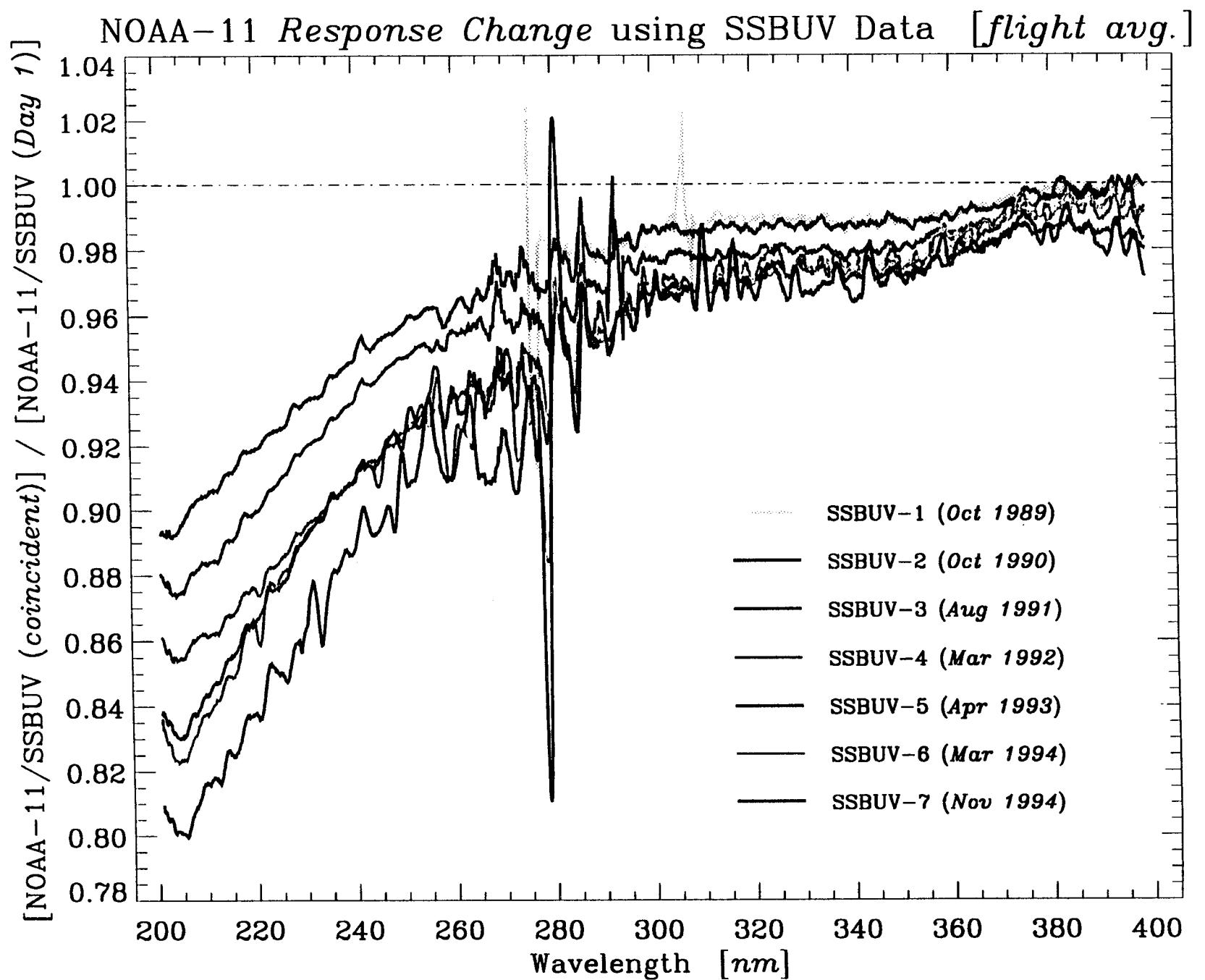
SSBUV MEASURED SOLAR IRRADIANCE CHANGE

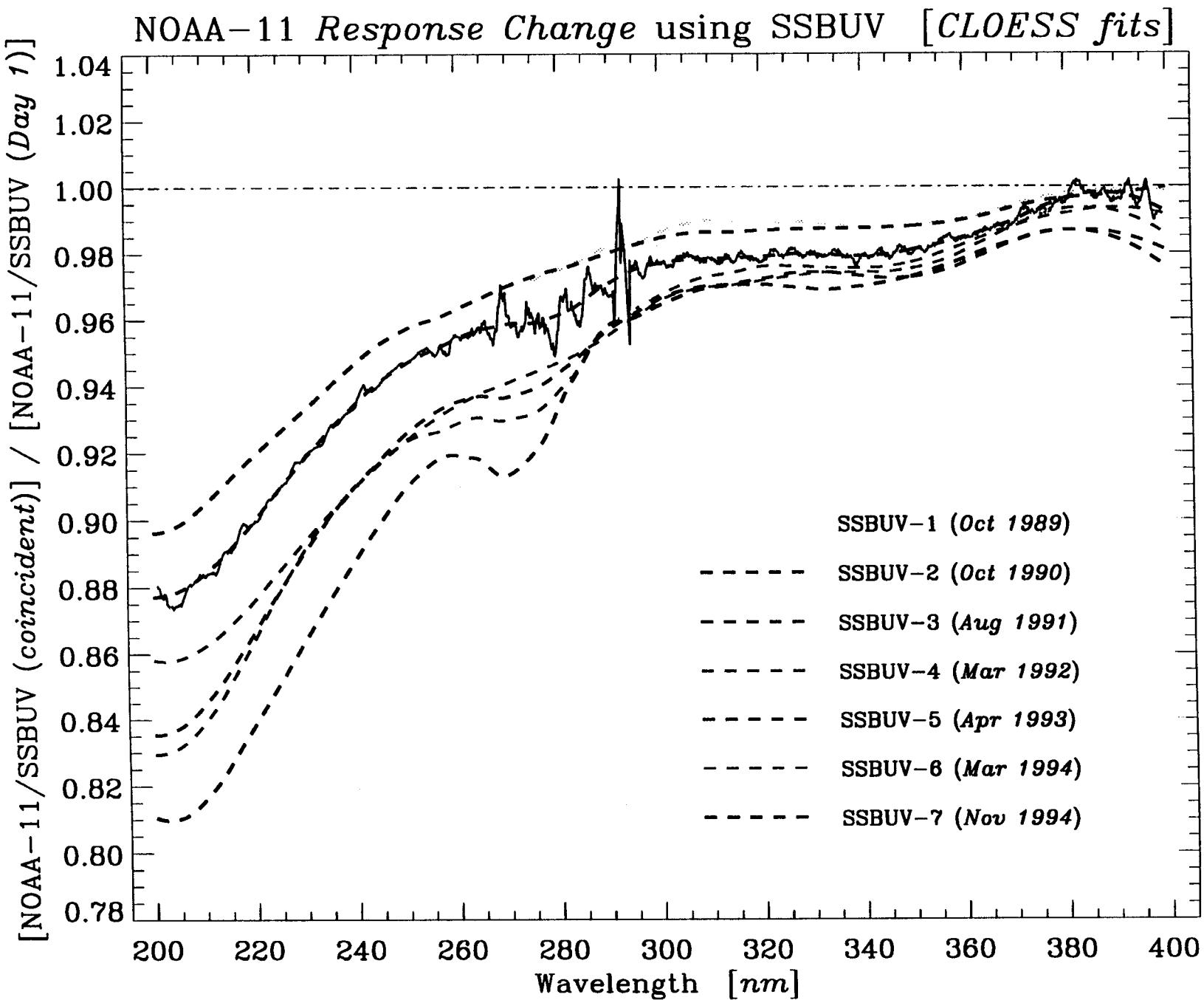




- ▶ Construct ratios of SSBUV flight averages and coincident NOAA-11 data. Use of coincident spectra removes solar change.
- ▶ Remove "Day 1" bias, normalize SSBUV data for each flight at 400 nm (adjustments are $\pm 0.5\%$ or less).
- ▶ Spectral dependence of NOAA-11 response change is fairly smooth. Small-scale structure caused by residual uncorrected wavelength scale drift.
- ▶ Fit each spectral ratio with **smoothing spline** function (CLOESS) to remove residual noise from $\Delta \lambda(t)$ correction, accurately follow large-scale structure.

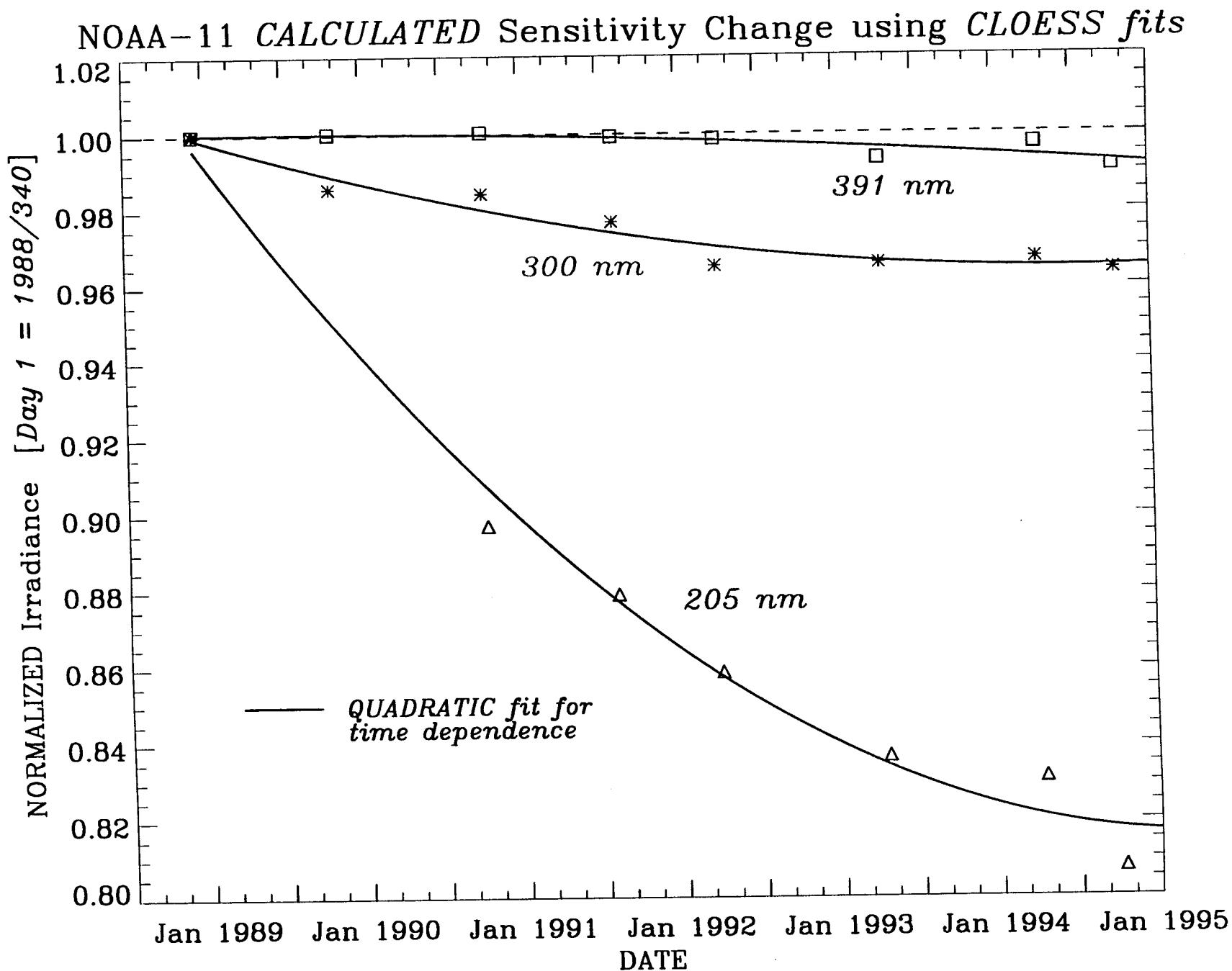
Characterize NOAA-11 *SPECTRAL* Response





- ▶ At each wavelength, construct **time dependence** using spectral fit values from each SSBUV flight and nominal "Day 1" value.
- ▶ SSBUV-1 data excluded for $\lambda < 275$ nm due to calibration problems.
- ▶ Limited number of points suggests simple time dependence. Quadratic fit works well, although upturn in late 1994 may not be realistic.
- ▶ True calibration changes with short time scales [$t < 1$ year] will not be well-represented.

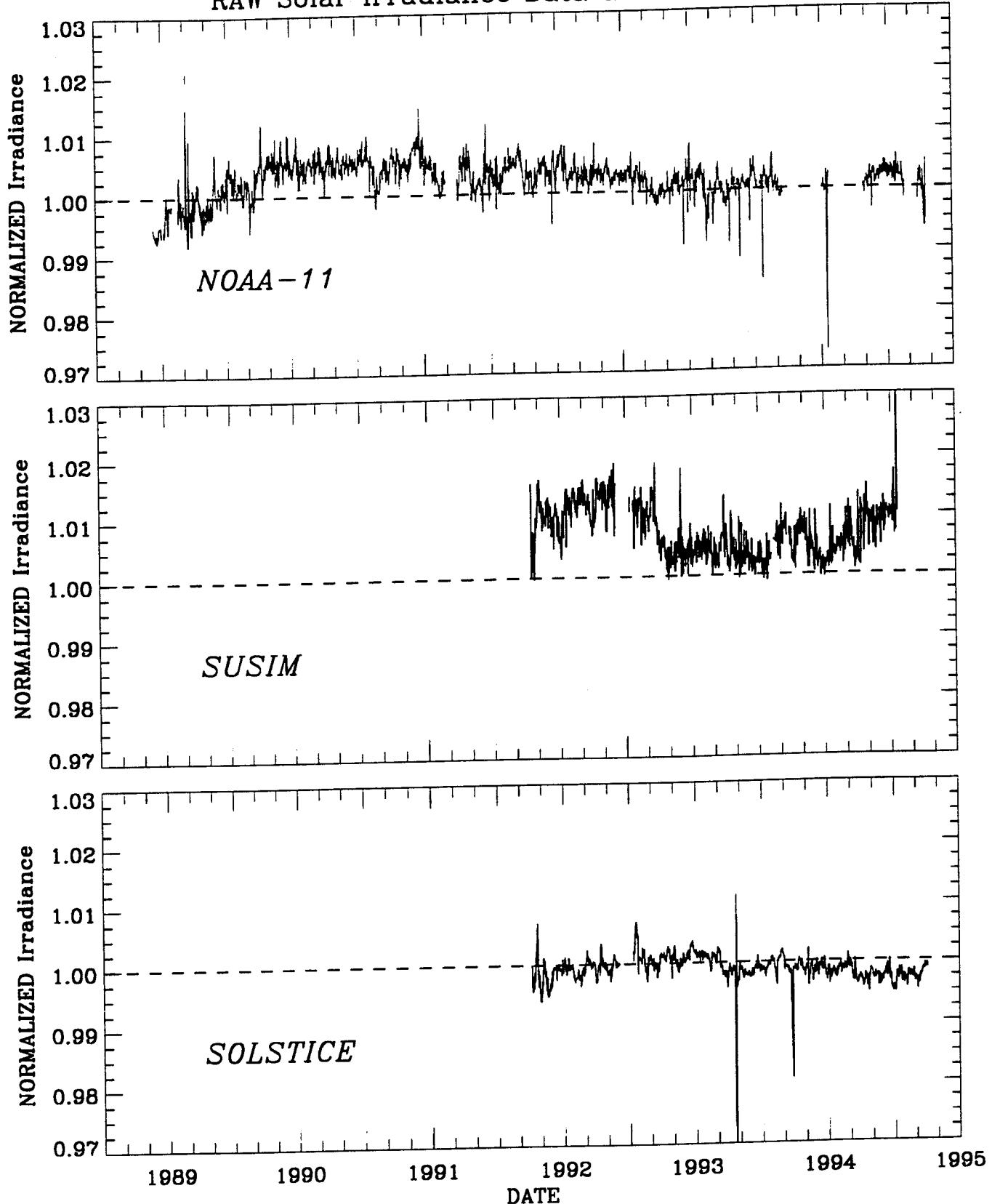
Characterize NOAA-11 *TEMPORAL* Response



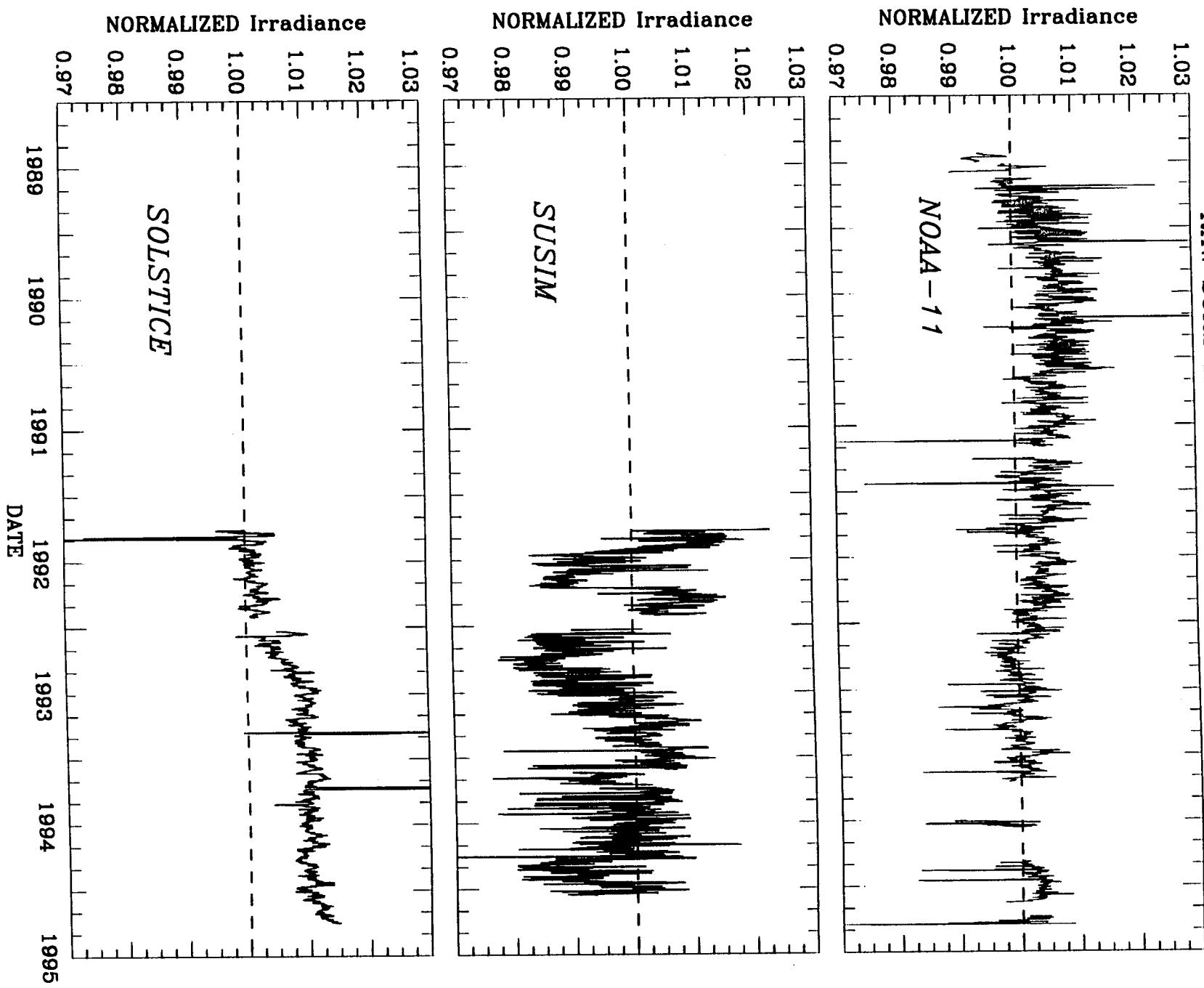
- ▶ NOAA-11 spectral data have adequate S/N down to 170 nm, but SSBUV-based correction only available for 200-400 nm. Spectral dependence of sensitivity change different at $\lambda < 200$ nm → can't extrapolate previous fits.
- ▶ Estimate sensitivity change at 170-200 nm by removing Mg II index-based predicted solar variation from time series. Fit remaining data with quadratic function for time dependence.
- ▶ Long-term correction for 170-200 nm less precise than 200-400 nm results based on SSBUV data.
- ▶ Select fit values at 5 nm intervals for dates of SSBUV flights, use as new "data" points with previous continuous ratios.
- ▶ CLOESS fits to full wavelength range preserve spectral structure for $\lambda > 200$ nm, give smooth shape for $\lambda < 200$ nm.

Short Wavelength Data

RAW Solar Irradiance Data at 340–350 nm



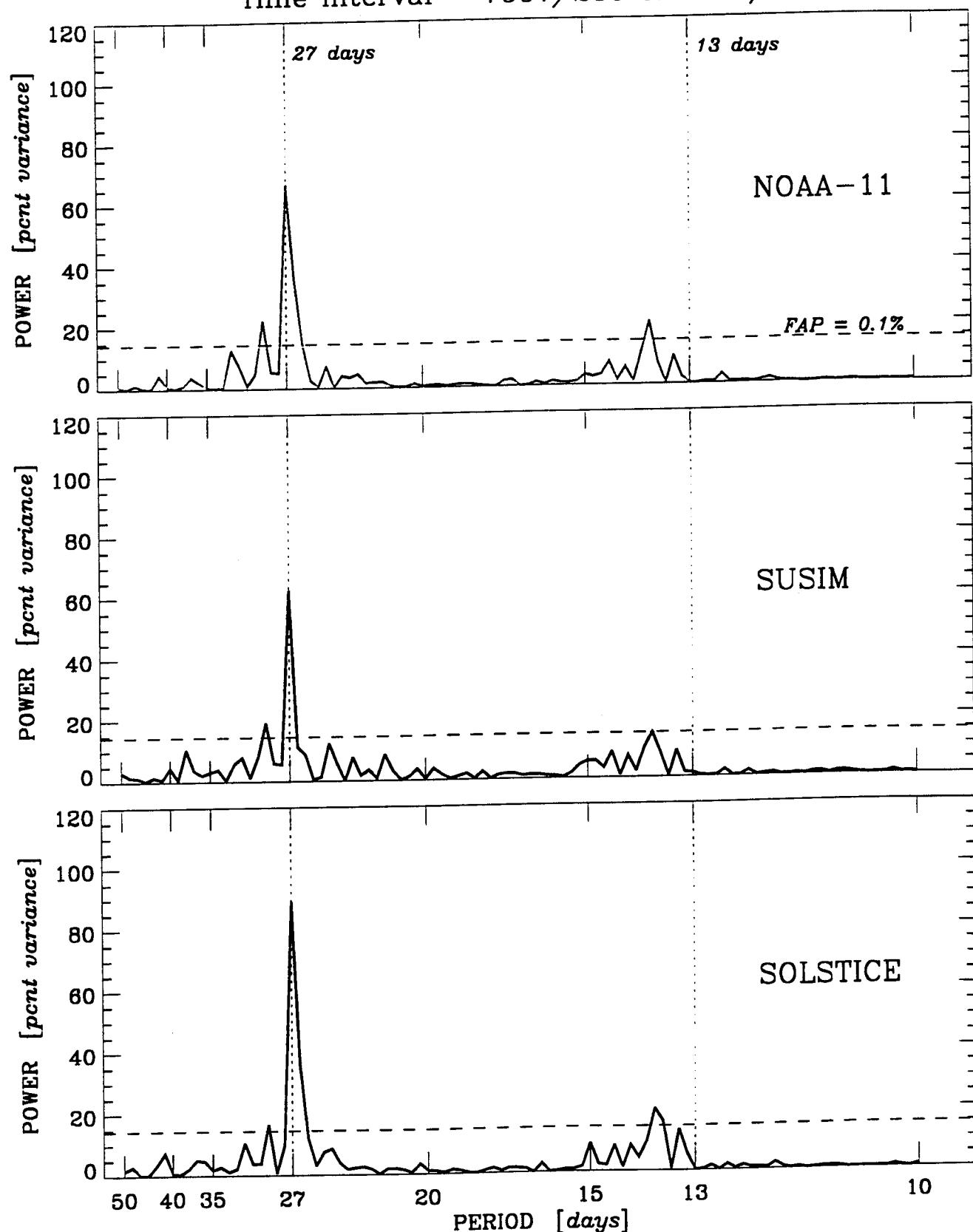
RAW Solar Irradiance Data at 380–390 nm



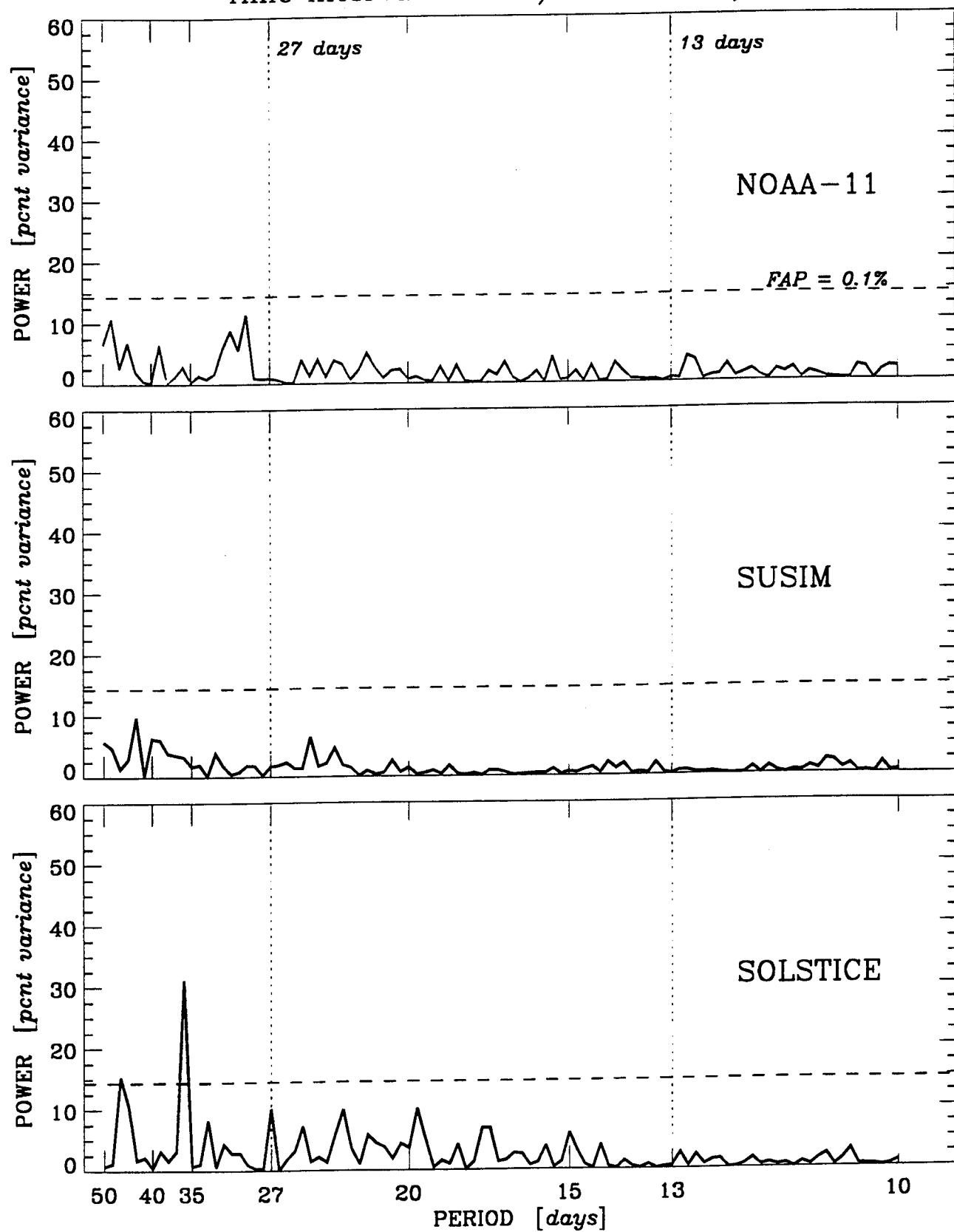
- ▶ NOAA-11 data cover complete solar maximum for Cycle 22. Long-term solar changes (*e.g.* end of maximum in Spring 1992) now visible at short wavelengths.
- ▶ Periodogram analysis shows consistent representation of short-term solar activity at 200-210 nm for all 3 instruments. 27-day rotational modulation present throughout 1991-1994, episode of 13-day periodicity observed in Fall 1991.
- ▶ Use NOAA-11 discrete Mg II index and scale factors to estimate solar activity during 1989-1994. Scale factors derived from short-term variations. Remove this estimate from all time series.
- ▶ Initial results indicate Mg II index predictions represent long-term solar activity to ~1-2% accuracy at 205 nm.

Observed Solar Activity

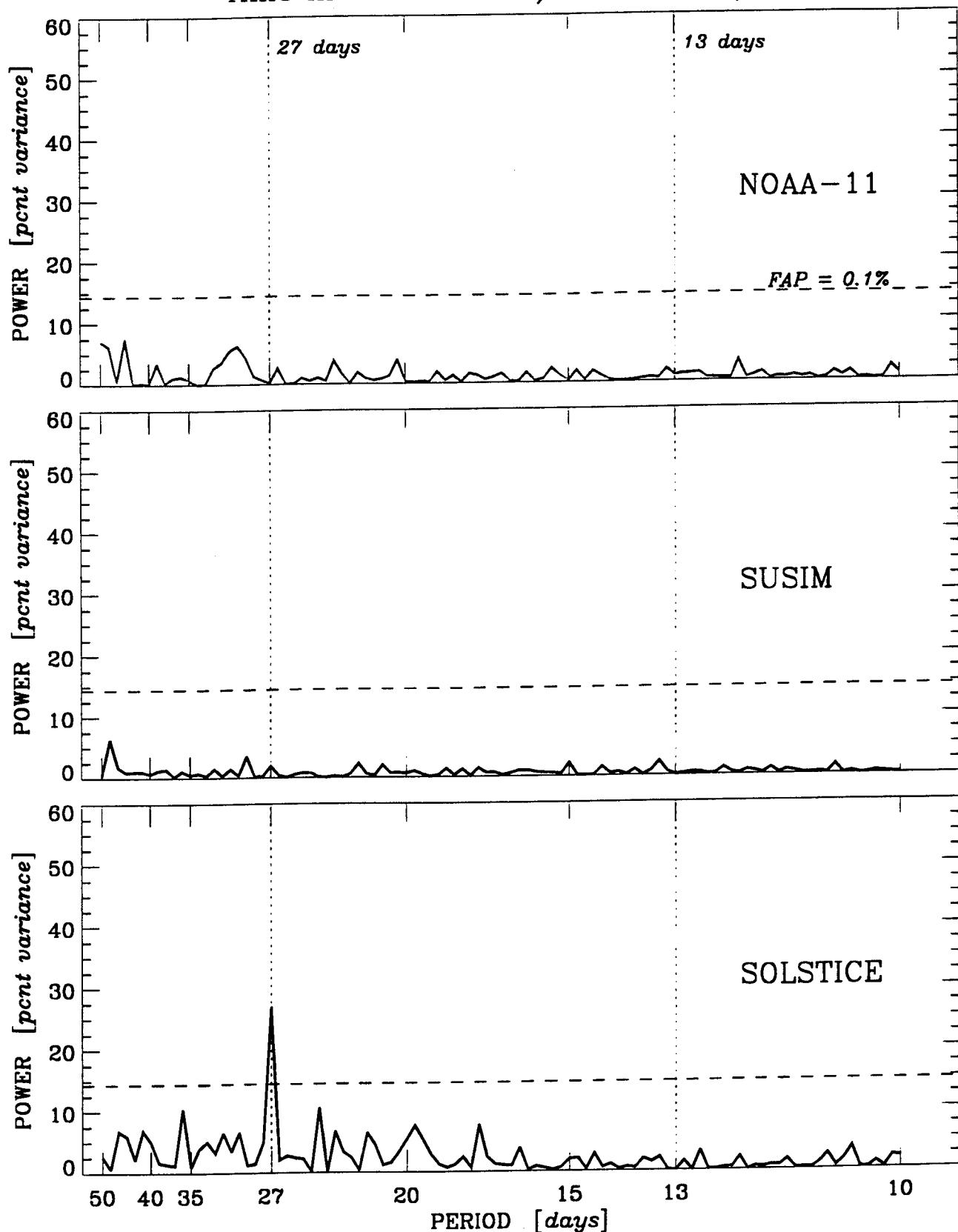
PERIODOGRAM for 200–210 nm Data
Time Interval = 1991/260 to 1994/289

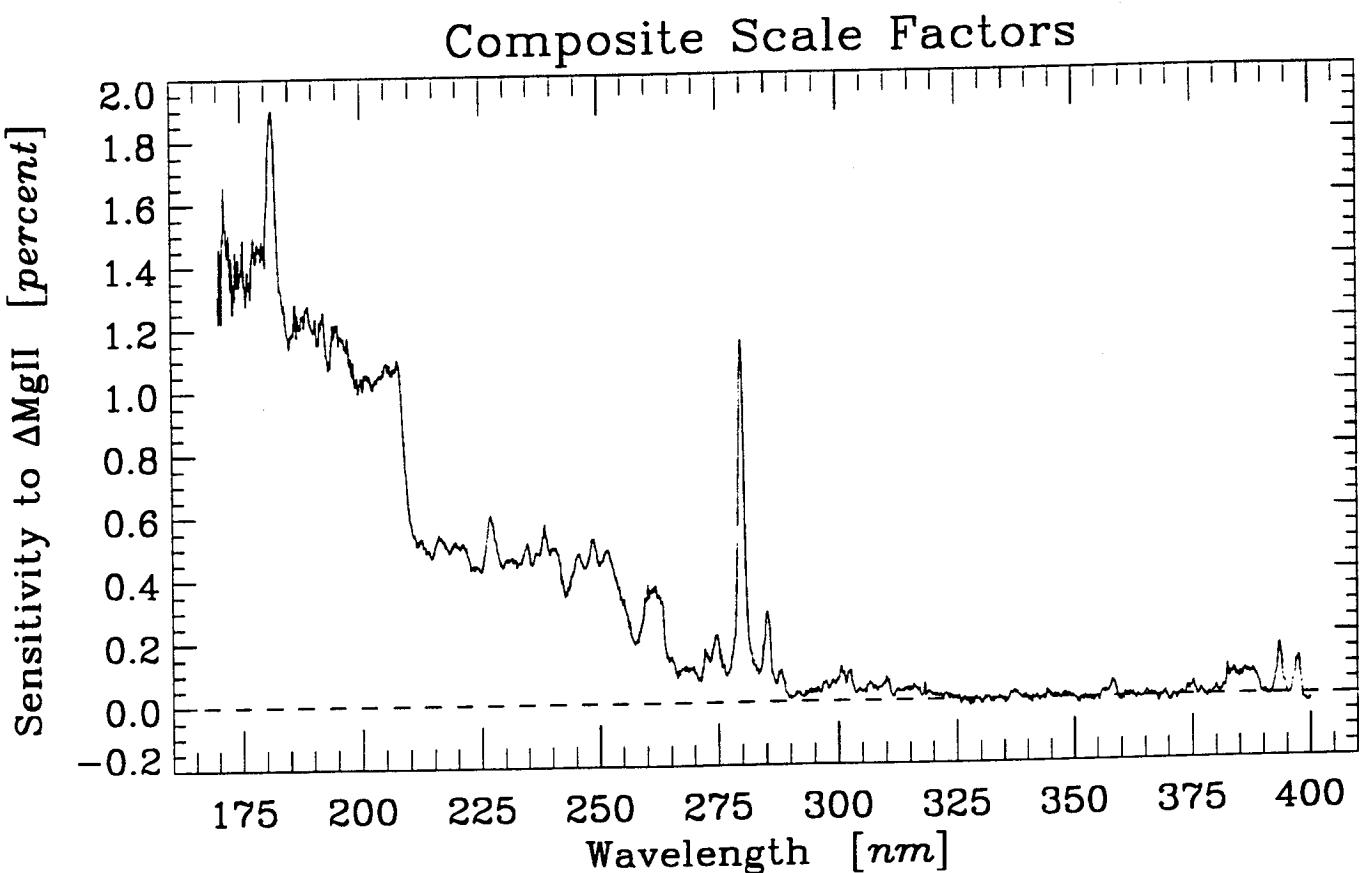
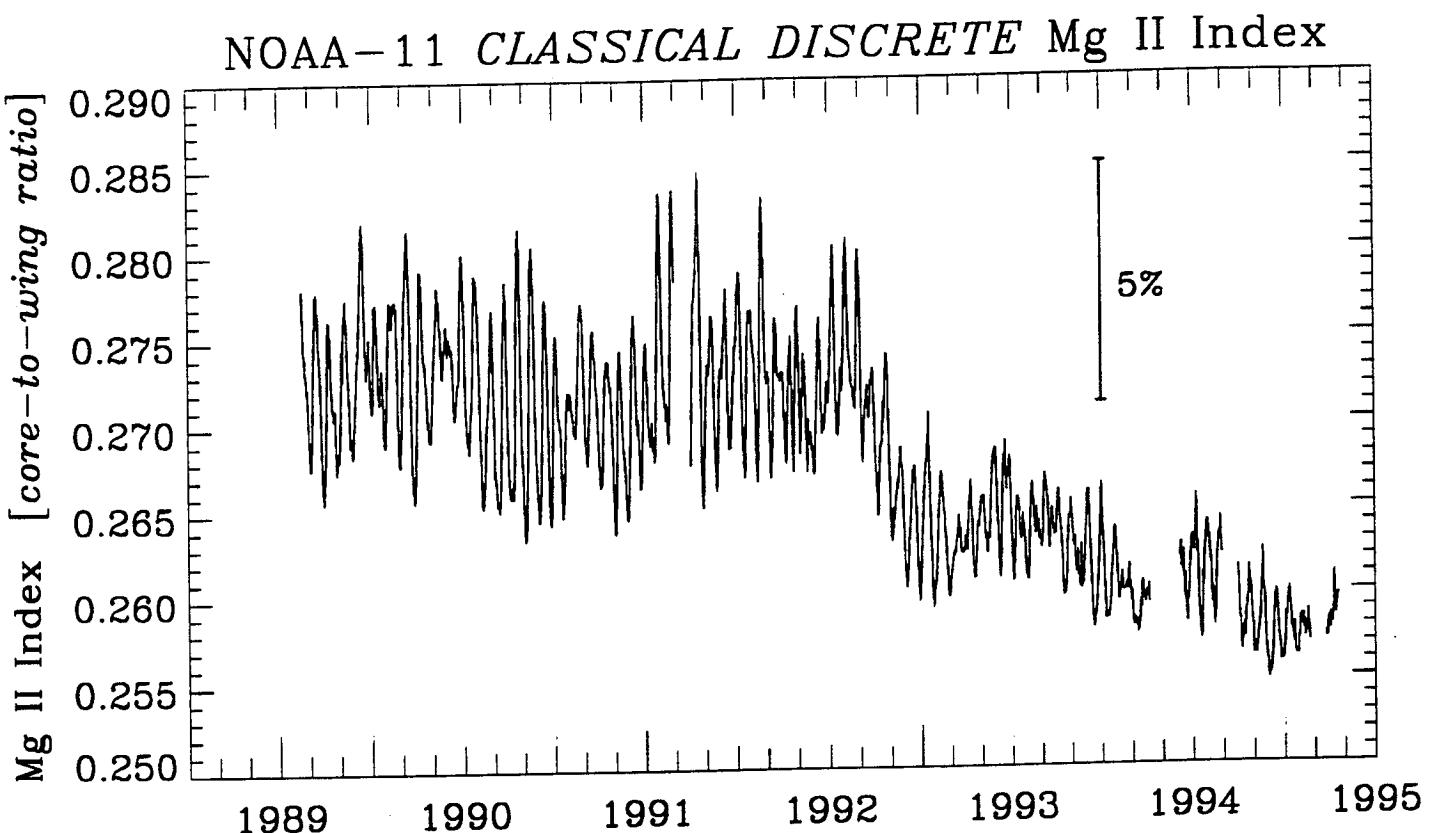


PERIODOGRAM for 340–350 nm Data
Time Interval = 1991/260 to 1994/289

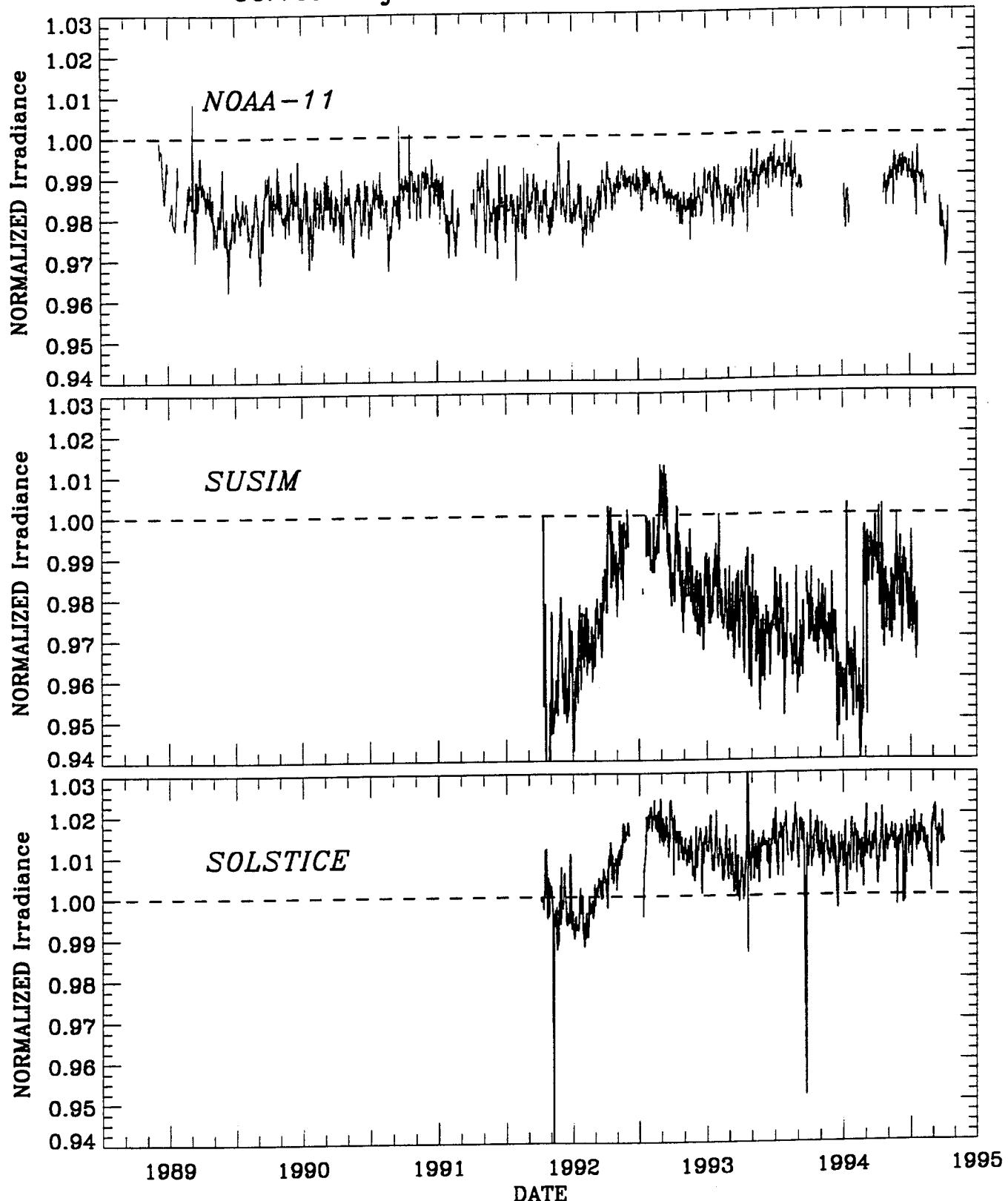


PERIODOGRAM for 380-390 nm Data
Time Interval = 1991/260 to 1994/289

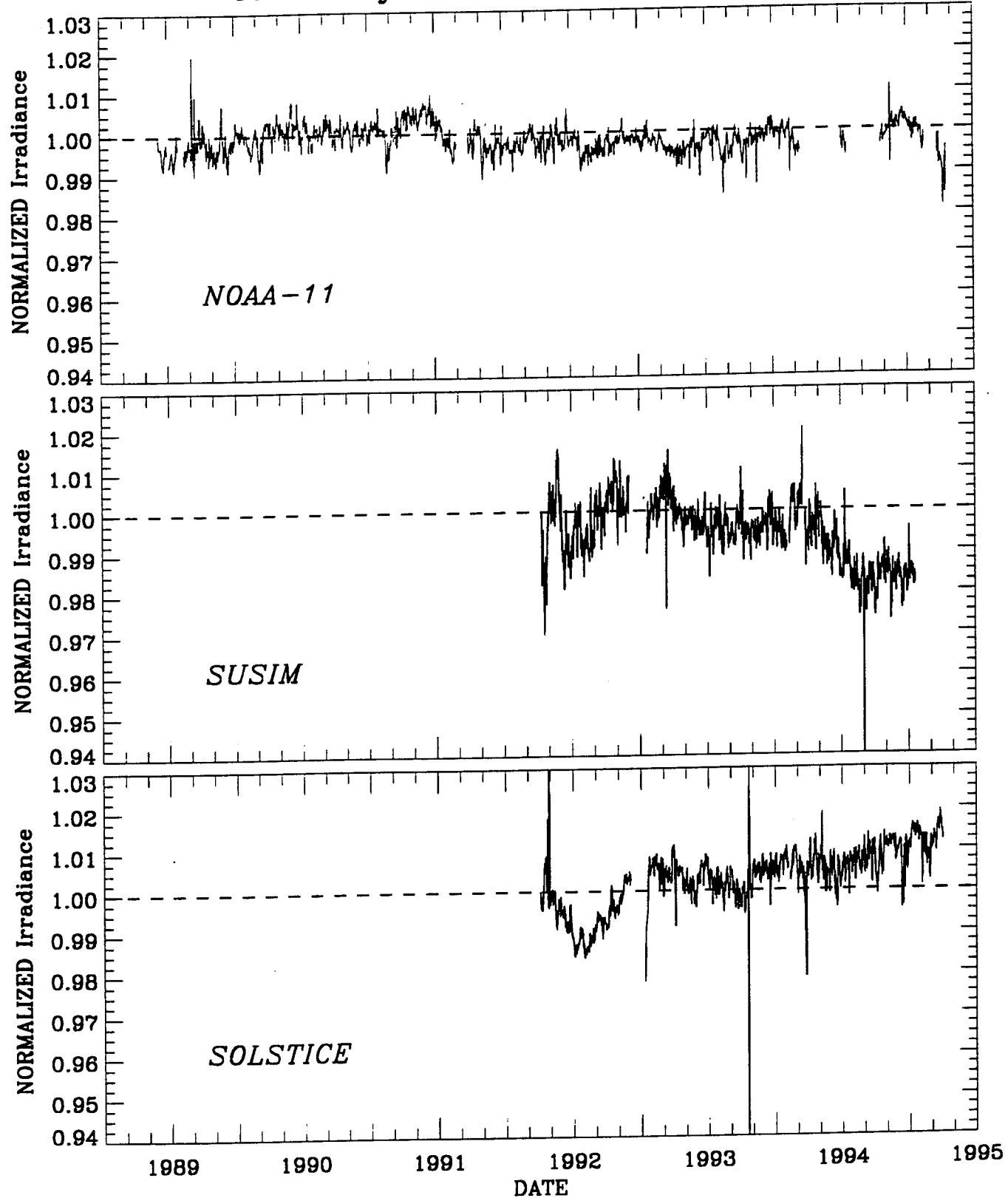




Irradiance Data at 200–210 nm
Corrected for ESTIMATED SOLAR CHANGE



Irradiance Data at 240–250 nm
Corrected for ESTIMATED SOLAR CHANGE



- ▶ NOAA-11 SBUV/2 solar irradiance data for December 1988 - October 1994 have been corrected for long-term instrument sensitivity changes using SSBUV comparisons.
- ▶ Residual long-term errors estimated to be approximately 1-3%. Results are comparable to UARS SUSIM, UARS SOLSTICE.
- ▶ Observed solar activity for maximum and decline of Cycle 22 consistent with Mg II index data.
- ▶ **NOAA-11 spectral irradiance data (1 nm average) will be available in early 1997. See signup sheet and/or authors if interested.** Full instrument sampling product ($\Delta\lambda = 0.15$ nm) also available on request.

CONCLUSIONS

SSBUV Measurements of Solar Spectral Irradiance Variations, 1989-1996

Richard P. Cebula

Hughes STX Corporation

Ernest Hilsenrath

NASA Goddard Space Flight Center

*Supported by NASA Grant NASW-4864 and
NASA Contract NAS5-31755*

AGU Fall Meeting, 19 December 1996

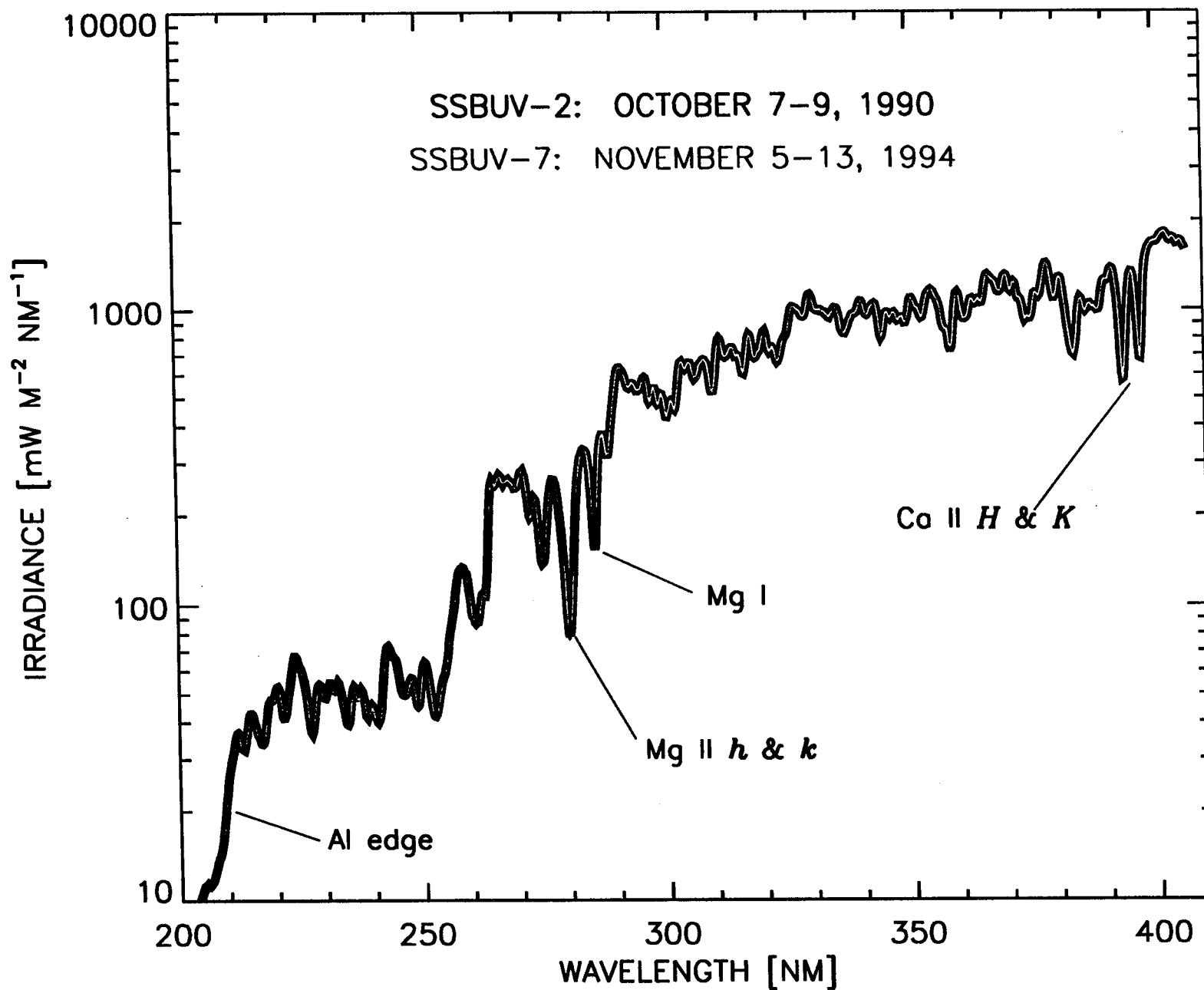
Outline

- Experiment overview
- SSBUV solar measurements
- Absolute solar irradiance comparisons
- SSBUV-measured solar change
- Solar Change comparisons
- Conclusions

SSBUV Overview

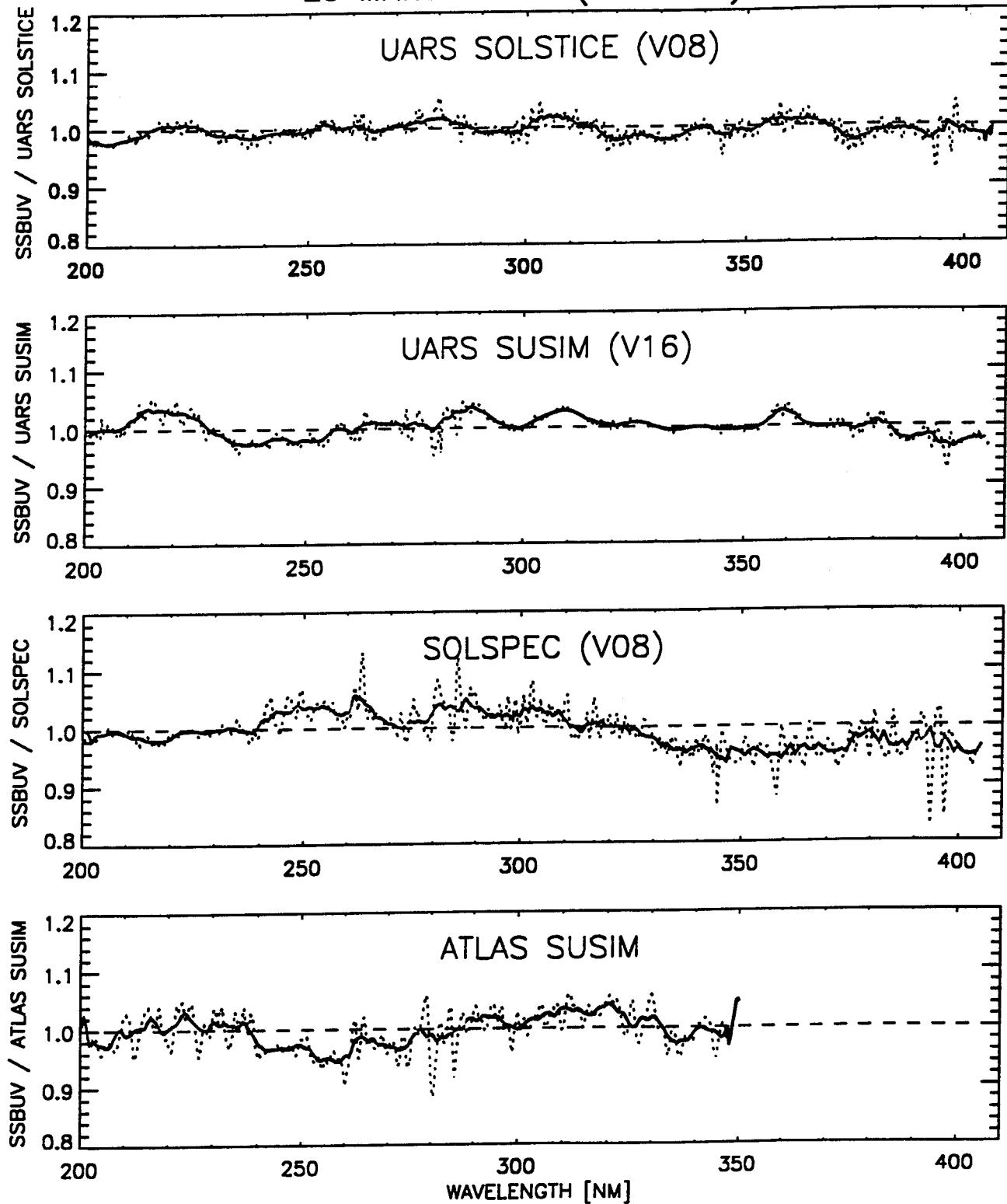
- Instrument Stats
 - spectral range: 200 - 405 nm
 - spectral resolution: 1.1 nm
- Uncertainties (2σ)
 - Absolute irradiance: 2.4 - 6.0%
 - Time dependence: 1.0 - 2.4%
- Missions
 - Eight flights: Oct. 1989 - Jan. 1996
 - Includes three ATLAS flights, Mar. 1992 - Nov. 1994
 - 6-8 scans/solar observation; 3-10 observations /flight

SSBUV SOLAR IRRADIANCE

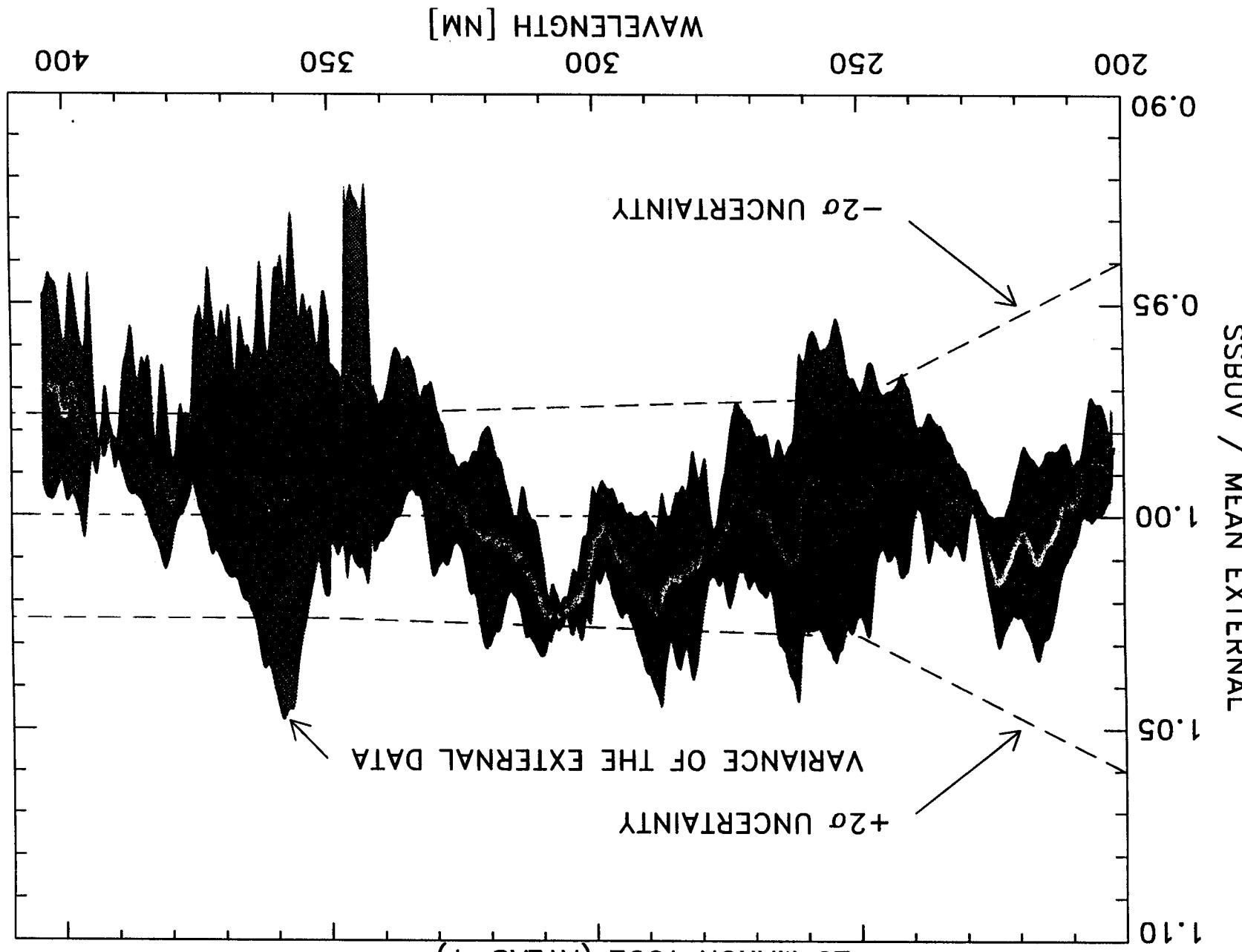


SOLAR IRRADIANCE COMPARISONS

29 MARCH 1992 (ATLAS-1)

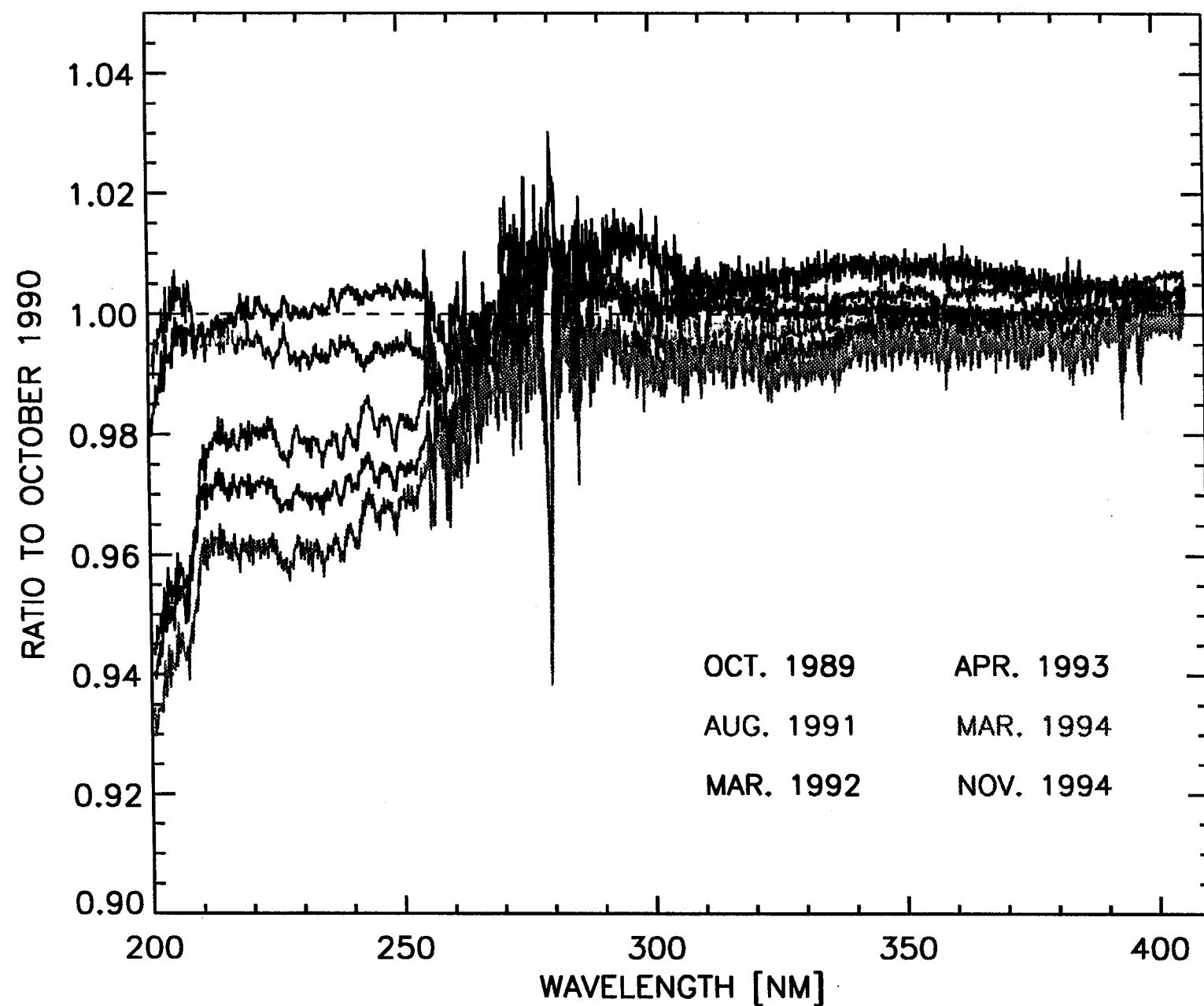


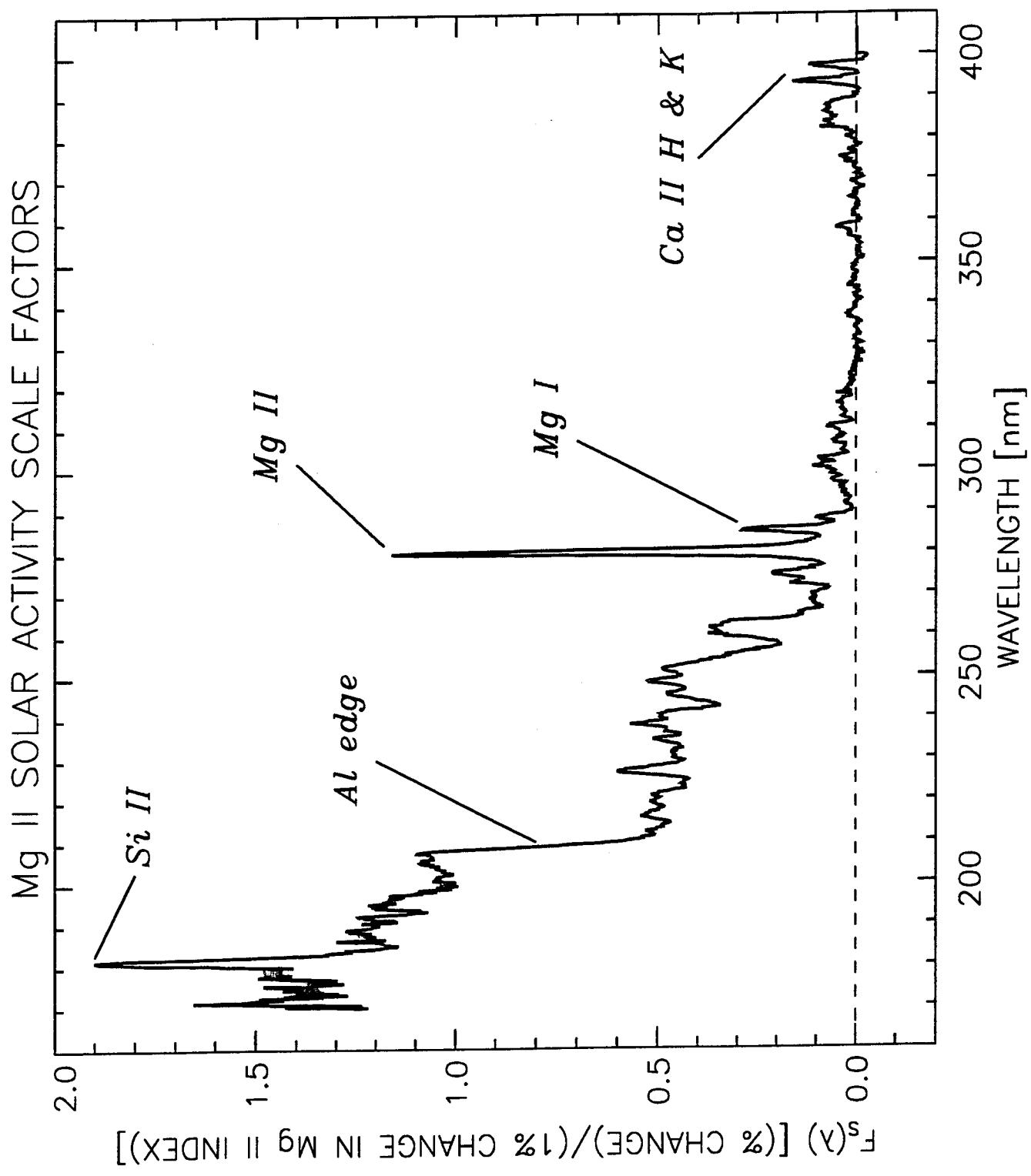
COMPARISON OF SSBUV TO OTHER SOLAR MEASUREMENTS



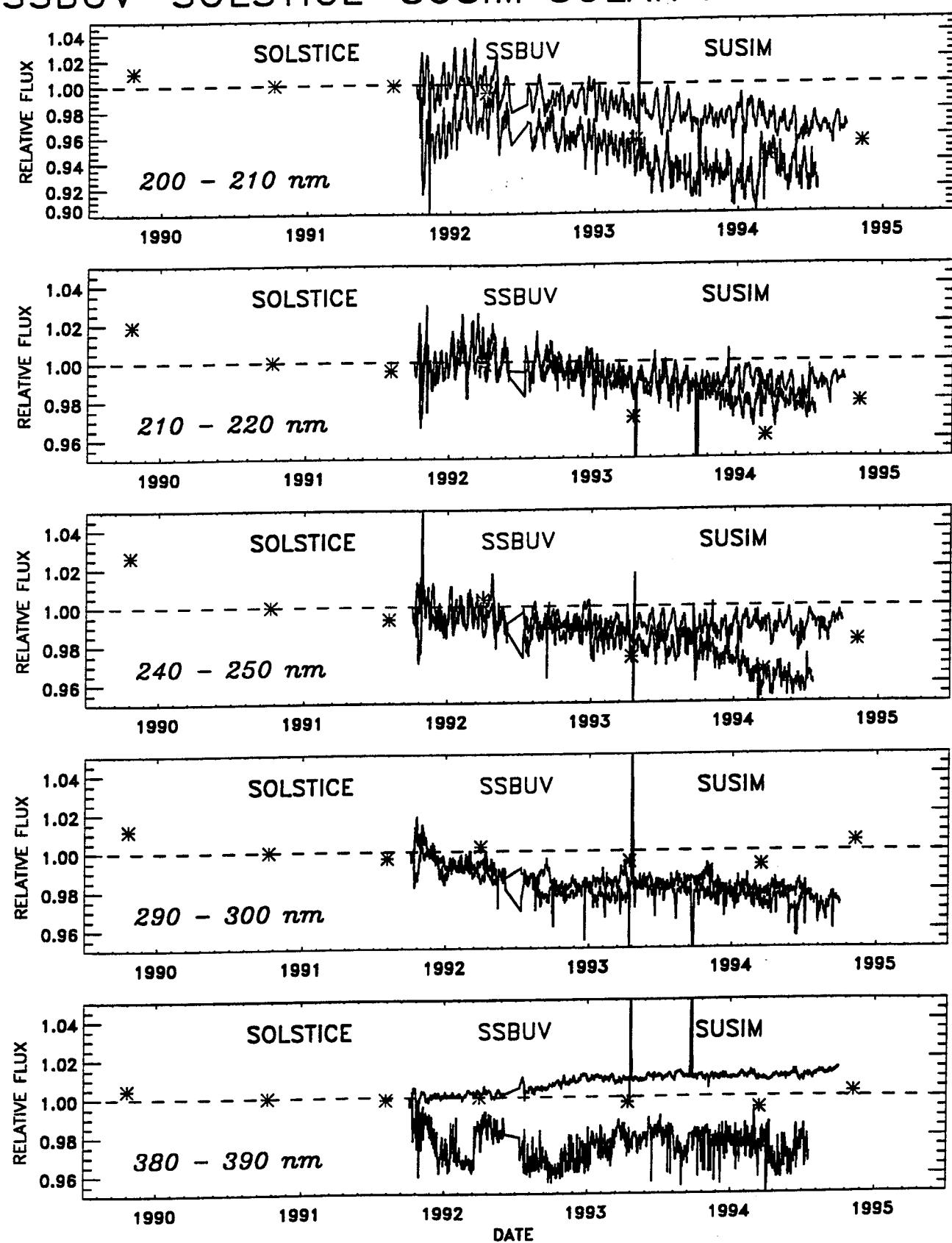
Note about refraction index: in January 1990, May, & 2000 CTD, see discussion for (refr. height); additional variability from δ
for $f_{\text{eff}} \approx 1 - 4$

SSBUV MEASURED SOLAR IRRADIANCE CHANGE





SSBUV-SOLSTICE-SUSIM SOLAR FLUX CHANGE



Conclusions

- Eight SSBUV missions 1989-1996
- SSBUV irradiances agree $\pm 2\%$ with mean of other solar flux measurements
- Measured long-term solar change ('90-'94)
 - 6.5% @ 200 nm
 - 3.0% @ 250 nm
 - less than 1% longward of ~ 300 nm
- SSBUV used to calibrate NOAA-11 SBUV/2
- **Data release anticipated in early 1997**

